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# Aeronautical Engineering REVIEW

1956–1957
IAS Roster of Members Issue

September, 1956

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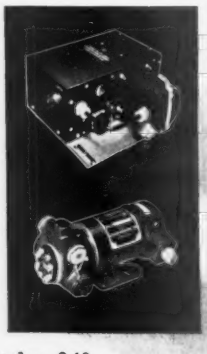

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# Aeronautical Engineering Review

Vol. 15—No. 9 September, 1956


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**Cover**—The Institute's 11,000 graded members and 3,000 Student Members have numerous opportunities to attend lectures, field trips, and social events. During the year there are half a dozen large national or international meetings, several joint meetings with other engineering societies, and some 250 local meetings, dinners, and inspection tours.


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CATALOG

# I.A.S. News Notes

September 1956

## "WE CONSIDER IT ANOTHER LONG STEP....."

Members' attention is invited to the Editorial, "Progress Report -- Vocational Guidance," in this issue of the Review for details on an Institute undertaking of vital importance to the aircraft industry.

THE THIRD INTERNATIONAL MEETING of the Canadian Aeronautical Institute and the Institute of the Aeronautical Sciences will be held November 26-27 at the Royal York Hotel, Toronto, Ont., Canada. Clifford C. Furnas, FIAS, U. S. Assistant Secretary of Defense, will be principal speaker at the dinner on the evening of the 26th.

COMPETITIONS OPENED. The Institute is inviting applications for another two-year Fellowship in Flight Test Engineering at Princeton University. Application forms may be secured by writing to Flight Test, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y. The letter requesting forms must be endorsed by a sponsoring reference. Complete details will be published in the October issue of the Review.

NEW IAS CORPORATE MEMBERS are Piasecki Aircraft Corporation, International Airport, Philadelphia, Pa., and C. W. Lemmerman, Inc., Hartford, Connecticut.

THEODORE VON KARMAN, HFIAS, AGARD Chairman for NATO, has received the honorary degree of Doctor of Science from Northwestern University. In the presentation, Dr. von Karman was referred to as "the statesman of modern engineering and a unique protagonist of the air age." Also stressed was his long list of contributions in many fields and his efforts in bringing about "the technological supremacy of his adopted country."

C. S. (CASEY) JONES, AFIAS, former Treasurer of the Institute, has been presented with the 1956 James H. McGraw Award in Technical Institute Education. The award lauds the "highly regarded" Academy of Aeronautics, of which Mr. Jones is President. (Details on Page 24.)

AMERICAN HELICOPTER SOCIETY. The Third Annual Western Forum will take place October 7-9 at the Adolphus Hotel, Dallas, Texas. Registration will be from Noon to 4 p.m. October 7 - free to IAS and AHS members. Brigadier General Carl I. Hutton, Post Commander, Army Aviation School, Fort Rucker, Ala., will be guest speaker at the Forum Dinner on October 8.

THE INSTITUTE MOURNS: Earl V. Farrar, AFIAS, Chief Engineer, Wright Aeronautical Div., Curtiss-Wright Corporation, died suddenly August 11 at his home in Ridgewood, N. J., after a heart attack. Representative Carl Hinshaw, MIAS, one of Congress' leading authorities on aviation, died on August 5 at Bethesda Naval Hospital, Washington, D.C. His death was blamed on pneumonia complicated by a heart condition.

## I.A.S. News Notes (con't.)

### NATIONAL MEETINGS CALENDAR

Nov. 26-27- International Meeting of the Canadian Aeronautical Institute and the IAS, Royal York Hotel, Toronto, Ont., Canada.

Dec. 17 - - Wright Brothers Lecture, U. S. Chamber of Commerce Building Auditorium, Washington, D. C. Sir Arnold Hall, Lecturer.

Jan. 28-31 - Twenty-Fifth Annual Meeting, Sheraton-Astor Hotel, New York.

* * * * * *

### SECTION MEETINGS CALENDAR

Sept. 11 -- Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Transcient Temperature Predictions in High Speed Aeronautical Structures by Use of Digital Calculators" by Lloyd Wilson.

Sept. 11 -- San Diego Section: Confidential Meeting, IAS Building, 8 p.m. "High Speed Aerodynamics" by Charles Frick.

Sept. 11-13- Chicago Section: Special tour of Pensacola Naval Air Station, Pensacola, Fla., and one-day cruise aboard the Carrier Saipan.

Sept. 12 -- Tulsa Section: Utica Square National Bank Building, Utica Square, 7:45 p.m. Election and regular business meeting. Showing of film: "History of Aviation."

Sept. 18 -- Cleveland-Akron Section: Manger Hotel, Cleveland. Social Hour 6 p.m.; Dinner 7 p.m.; Meeting 8 p.m. "The DC-8 Airplane" by Harry Hjorth.

Sept. 20 -- Los Angeles Section: Dinner Meeting, IAS Building. Social Hour 6 p.m.; Dinner 7 p.m.; Meeting 8 p.m. "Activities at Edwards Air Force Base" by Colonel Horace A. Hanes, USAF.

Sept. 25 -- Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Panel Flutter of Cylindrical Shells" by John W. Miles.

Sept. 25 -- San Diego Section: Dinner and Annual Business Meeting, IAS Building, 7 p.m. "Nuclear Power" by C. L. Critchfield.

Sept. 27 -- Dayton Section: Tour, Area B, Wright-Patterson Air Force Base, 6:30 p.m. Visit to WADC Power Plant and Propeller Labs.

Sept. 27 -- Washington Section: Dinner Meeting, Occidental Restaurant. Dinner 6 p.m.; Meeting 8 p.m. "Dynamics of Dissociating Gas" by M. J. Lighthill.

Oct. 8 -- Indianapolis Section: Dinner and Business Meeting, Marott Hotel. Dinner 7 p.m.; Meeting 8 p.m. "The Electra Aircraft" by Howard McGlasson.

Oct. 20 -- Los Angeles Section: Dinner Meeting, IAS Building. Social Hour 6 p.m.; Dinner 7 p.m.; Meeting 8 p.m. Remarks by Rear Admiral James S. Russel, USN.

Nov. 12 -- Indianapolis Section: Dinner Meeting, Union Hall, Purdue University, West Lafayette. Dinner 6 p.m.; Meeting 7 p.m. "Rocket Development" by C. F. Warner.

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# IAS News

*A Record of People and Events of Interest to Institute Members*

## National Summer Meeting Report

### *Von Kármán's 75th Anniversary Celebrated*
### *Chanute Award Presented to "Tex" Johnston*

This year's National Summer Meeting, held in Los Angeles, June 18–21, set some new highs in attendance and overall interest. With more than *860* people registered for the technical sessions and some 1,100 persons attending the dinner, this turned out to be the largest National meeting so far held by the Institute on the West Coast.

▸ **Technical Sessions**—All of the technical sessions were well attended—particularly the two security-closed sessions on the "B-52 Development" and "Supersonic Propulsion for Aircraft and Missiles." None of the papers presented at these confidential sessions will be published by the Institute, of course. The majority of papers presented at the open sessions are available in preprint form (see p. 329). Many of them are being published in full in this and subsequent issues of the REVIEW. Meanwhile, summaries of the open sessions have been written by the various coordinators, and these will appear in the October issue of the REVIEW.

▸ **March Field Trip**—On Thursday, June 21, 225 security-cleared members took advantage of the Air Force invitation to visit March AFB at Riverside, Calif. Here, the group was briefed on the activities and operations of the 15th Air Force, under the command of Major Gen. Archie J. Old, Jr. Luncheon at the Officer's Club, a tour of Base facilities, and briefings by the various commanding officers provided a valuable insight into some of the problems and operations of the Strategic Air Command.

▸ **Banquet**—This year's Summer Meeting Dinner honored Theodore von Kármán on his 75th Anniversary. The theme of the entire program, including the principal address by Hugh L. Dryden, was "Theodore von Kármán's Deepening Impress upon Aeronautical Science and Engineering."

Dr. Dryden, after citing many incidents of Dr. von Kármán's life and achievements, concluded his address with the following tribute:

"Although I have merely mentioned the titles of a few of von Kármán's more than 135 books and papers, I believe that members of this audience recognize the powerful influence of those papers on aeronautical science and engineering and even on scientists and engineers who have not had the good fortune to know him personally. But far more important is the ever-widening influence of his personality spread by the hundreds of students from Aachen to Pasadena who were taught to isolate the essential physical concepts of a complex engineering problem, to apply suitable mathematical analysis, and to evaluate the results in practical terms. They have been inspired to their maximum of creative effort and infected with enthusiasm for scientific work. Many of them have been able to transmit this inspiration to their own students and collaborators, becoming leaders in their own right. In this way von Kármán's personality and work are making an ever-deepening impress.

"Those of us within his large circle of friends and collaborators can never forget his human qualities, his friendliness, his sense of humor, his interest in each person as an individual, and his stimulating views on art, philosophy, and other human affairs. . . ."

Other tributes and honors given Dr. von Kármán on this occasion included: the Presidential Medal of Freedom, presented by Major Gen. R. P. Swafford, Jr., USAF; a message from the Secretary of the Navy, delivered by Rear Adm. J. B. Pearson, Jr., USN; two leather-bound volumes containing over 1,000 congratulatory letters from friends and former students; a special leather-bound issue of the JOURNAL OF THE AERONAUTICAL SCIENCES; a birthday cake from the Aircraft Industries Association; and tributes from ten of the other major professional societies and technical institutes of the country.

(See following pages for photos of dinner.)

**IAS President E. R. Sharp presents Octave Chanute Award to A. M. "Tex" Johnston.**

▸ **Chanute Award**—The Octave Chanute Award for 1956 was presented during this dinner by IAS President E. R. Sharp to A. M. "Tex" Johnston, Chief of Flight Test, Boeing Airplane Co., for "combining the practical with the scientific approach in the initial flight testing and evaluation of high-performance jet aircraft and engines."

Theodore von Kármán and IAS President E. R. Sharp discuss merits of the 75th Anniversary cake presented to von Kármán by the Aircraft Industries Association.

## NATIONAL SUMMER MEETING DINNER

Los Angeles, Calif.
June 20, 1956

Von Kármán's appreciation of the tributes paid him on this occasion are best expressed by this personal letter to IAS Director S. Paul Johnston.

THEODORE VON KÁRMÁN
1001 SOUTH MARENGO AVENUE
PASADENA, CALIFORNIA

July 18, 1956

Mr. S. Paul Johnston
Institute of the Aeronautical Sciences
2 East Sixty-Fourth Street
New York 21, New York

Dear Paul:

I was sincerely overwhelmed by the signs of friendship and affection which you and members of your organization have shown on the occasion of my 75th birthday. The special issue of the Journal of Aeronautical Sciences, May, 1956, which contained original articles of leading aeronautical scientists and engineers who were my former students, constitutes an extremely valuable high level contribution to modern aeronautical science. I wish to express my appreciation to the authors, and for the work of the editing committee consisting of Hugh L. Dryden, William R. Sears, Frank Wattendorf and Robert R. Dexter.

I particularly want to express my gratitude to the anonymous group known as "The Friends and Students of TVK." This group produced two volumes beautifully bound and containing over a thousand personal greetings from my friends and former students. I suspect that the manager and a number of members of your Western Division played the greatest part in the organization of this lovely surprise.

I also want to express my thanks to the representatives of the Armed Services, scientific and professional institutions who transmitted greetings of their organizations.

Finally, I don't want to forget the beautiful birthday cake which the aircraft industries contributed to the testimonial dinner on June 20. I keep under my treasured souvenirs the pylon with the rocket on the top and the alternating light in the interior.

With the kindest personal regards in old friendship,

Theodore

Theodore von Karman

TvK:nlg

**Judges and student speakers at the Sixth Annual West Coast Conference of Student Branches. *Left to right:* Milford G. Childers, K. E. Van Every, William M. Foley, Warren S. Wilson, Clay W. Whybark, Alfred C. Thomas, Bud D. Nelson, Theodore A. Heinz, Leroy L. Presley, Ely S. Levinsky, Charles A. Yost, Jack E. Coppage, Bill L. Coffey, Rodney D. Hugelman, and Donald L. Baxter.**

# Sixth Annual West Coast Student Conference Attracts a Record Attendance of 200

The Sixth Annual West Coast Conference of Student IAS Branches opened at the Institute Building, Los Angeles, on Thursday, May 3, at 10:00 a.m. with a welcome by George Mellinger, Chief of Flight Test, North American Aviation, Inc., who is Chairman of the Los Angeles Section. Mr. Mellinger also served as Master of Ceremonies at the banquet Friday evening.

Approximately 200 students and faculty members, representing seven student branches, attended the conference. This attendance was the largest to date.

Buffet luncheons were served on Thursday noon with The Garrett Corporation as host and on Friday noon with Lockheed Aircraft Corporation as host.

The morning sessions of the conference were devoted to the presentation of graduate and undergraduate papers. The papers covered broad subject matter. The student MC's during the presentation of the papers were Bud Nelson, of the University of Washington, and Vic Peterson, of Oregon State College.

During the afternoons, the conferees were occupied with field trips. Thursday the group visited The Garrett Corporation at Los Angeles International Airport. Friday afternoon the students toured the Southern California Cooperative Wind Tunnel in Pasadena, Calif. They were shown the various features of the new multimillion-dollar installation. Transportation to and from the installation was provided by Northrop Aircraft, Inc.

Thursday evening the conferees enjoyed a social hour and dinner as guests of Douglas Aircraft Company, Inc. Following the dinner, officers of the student branches represented reported on the various activities of each branch. Subsequent to these reports, a panel discussion on the subject of "Engineers in Industry" was held. The panelists included industry. This innovation in the program, introduced this year, gave the students an opportunity to participate and to ask experts detailed and frank questions concerning their futures.

The Friday evening banquet program commenced with the awards for the technical paper competition. E. W. Robischon, Western Region Manager of the IAS, made the presentations.

A prize of $100 and an IAS plaque was awarded for the best paper on the graduate and undergraduate levels. Second prize consisted of $50 and an IAS certificate awarded in each division. The winning papers were:

**Students attending the Sixth Annual West Coast Conference sit in the shadow of the Wright brothers' biplane replica at a luncheon in the auditorium of the IAS Building.**

*First prize* (graduate paper)—"Approximate Compressible Laminar Skin Friction with Fuselage Pressure Gradients," by Ely S. Levinsky, University of Washington.

*First prize* (undergraduate)—"Gyroscopic and Variable Center of Gravity Forces for a New Design in VTO Aircraft," by C. A. Yost, Northrop Aeronautical Institute.

*Second prize* (graduate)—"An Investigation of the Performance of Sharp-Edged Jet Engine Inlets at Zero Forward Velocity," by Leroy L. Presley, Oregon State College.

*Second prize* (undergraduate)—"An Experimental Study on Induced Turbulent Boundary Layer on Model Airfoils at Very Low Reynolds Number," by B. D. Nelson, University of Washington.

*Honorable mention* (undergraduate)—"The Development of an Experimental Liquid Oxygen-Thiokol Rocket Propulsion System," by Theodore A. Heinz, Northrop Aeronautical Institute.

All student speakers were presented with desk models donated by the local aircraft industry.

The speaker at the banquet was Lt. Gen. Laurence C. Craigie, USAF (Ret.), former Deputy Chief of Staff for Development. He flew the P-59 as America's first jet pilot. Speaking on the topic "The Future Belongs to the Engineer," he pointed out the increasingly important role of the engineer in tomorrow's technological civilization.

D. J. Scrooc

**Clark B. Millikan, an Honorary Fellow of the IAS, snapped at the West Coast Industry-Faculty Conference. He is Director of the Southern California Cooperative Wind Tunnel at Caltech.**

# Educators Discuss Cooperative Programs with West Coast Industry

The Third Annual West Coast Industry-Faculty Conference held at the IAS Building, Los Angeles, on the evening of May 2, was attended by more than 50 West Coast educators and aircraft industry representatives. The meeting was preceded by a social hour and buffet sponsored by Boeing Airplane Co.

Following the social hour, the Master of Ceremonies, H. D. Moran, presented a report on the activities of the Engineering Career Development Committee formed as a result of last year's conference. The evening's discussion, moderated by F. C. Lindvall, Chairman of the Division of Engineering, California Institute of Technology, considered the timely subject of "Cooperative Programs." The purpose of this discussion was to permit an informal interchange of ideas and problems between college staff and aircraft industry management.

The major points discussed were part-time employment for students, part-time employment for faculty, and the integration of industry personnel in academic curriculum. During the discussion, several cooperative work-study programs for undergraduate and graduate students presently offered or proposed by various colleges were described.

On the subject of part-time industrial employment for faculty members, discussion centered on a recent proposal that industry employ faculty members for the first two months during the summer and continue to pay their salaries and expenses during the final summer months spent at a teaching seminar. Some possible disadvantages mentioned were that faculty members, because of their limited availability, would be assigned relatively low-priority work and would rarely be given an opportunity to observe closely design aspects of aeronautical engineering. It was suggested that some of industry's engineering work could be contracted directly to the colleges, thus providing another means of assisting students financially.

The problem of raising academic salaries was briefly examined. The discussion was confined to possible sources of funds and how to allocate such funds, if available, in a manner consistent with the normal university policy of maintaining uniform salaries in each department.

D. J. Scrooc

**Fred C. Lindvall *(left)*, Chairman of the Division of Engineering, California Institute of Technology, and Harold Conrad, Vice-Chairman of the Student Affairs Committee, Los Angeles Section, meet at the punch bowl during the IAS Industry-Faculty Conference.**

## Marquardt Engineers Sponsor "Science Scouts"

America's first troop of "Science Scouts" has been formed in Van Nuys, Calif., by a group of engineers connected with the Marquardt Aircraft Company.

President Roy E. Marquardt, AFIAS, and Chief Technical Engineer Joseph Friedman, MIAS, were active in organizing and sponsoring the troop, which has received its official charter from the Boy Scouts of America. It is known as (Science) Explorer Post No. 501 and has 25 members between 14 and 17 years of age.

The result of a casual discussion on "How can we get high school boys in-

terested in an engineering career?," the Explorer Post was organized in March and had programs on nuclear engineering, geology, and electronics during its first 3 months.

As an experiment, the engineers invited a group of Air Scouts to visit the Marquardt plant. They were exposed to a few semitechnical lectures. Talking with the boys afterwards, the host engineers found that they were enthusiastic about the tour, "surprisingly technical" in their discussion, and eager to learn more.

Sons of several of the engineers belong to the new Explorer Post.

The sponsoring engineers are already writing a proposed handbook for Science Scouts.

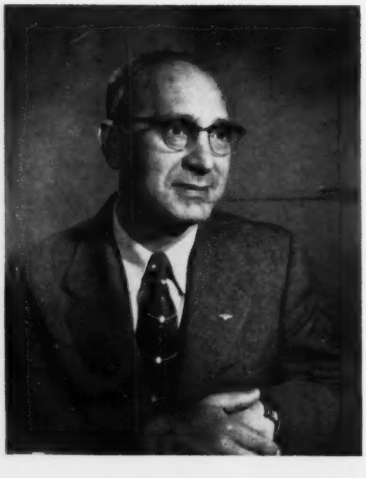
To quote Mr. Friedman, who is Chairman of the Advisory Committee of (Science) Explorer Post No. 501: "We at Marquardt are delighted with the results of this experiment. We feel we have demonstrated that this is a feasible way industry can help in whittling down the long-range shortage of engineers and scientists while, at the same time, providing a constructive outlet for the seemingly boundless energies of these young men."

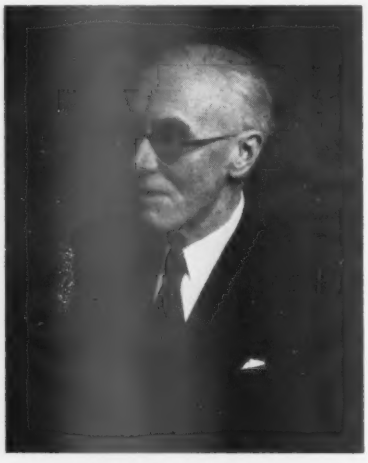
## I. E. Garrick Chosen for Hunsaker Chair at M.I.T.

I. Edward Garrick, AFIAS, Chief of the Dynamic Loads Division of Langley Aeronautical Laboratory, NACA, has been appointed to the Jerome Clarke Hunsaker professorship at Massachusetts Institute of Technology for the coming academic year. He succeeds William R. Hawthorne, MIAS, of Cambridge University, England.

During his year at M.I.T., beginning this month, Mr. Garrick will teach and do research in the Department of Aeronautical Engineering, concentrating on studies of flutter, aeroelastic problems,

I. E. Garrick





Sir Richard V. Southwell

and aerodynamic phenomena. One of his responsibilities will be to deliver the Minta Martin Lecture next spring.

A graduate of the University of Chicago, Mr. Garrick joined the NACA as a physicist in 1931. At Langley, he has specialized in theoretical aerodynamics, aircraft vibration and flutter, gas dynamics, and applied mathematics.

The endowed professorship was established in 1954 to honor Dr. Hunsaker, Chairman of the NACA since 1941, who organized America's first aeronautical engineering course at M.I.T.

## Sir Richard Southwell is Visiting Professor at Rice

Sir Richard V. Southwell, an Honorary Fellow of the IAS, has joined the faculty of The Rice Institute, Houston, Tex., as Visiting Professor of Mechanical Engineering for the coming school year.

The retired British educator, an authority in the field of relaxation methods and theory of elasticity, will teach a full year's course in these subjects. A series of public lectures also is planned.

Active in aviation since 1914, Sir Richard was Professor of Engineering Science at Oxford University, England, from 1929 to 1942. For the next 6 years he was Rector of the Imperial College of Science and Technology, University of London. He has written four textbooks and numerous technical papers and is a Fellow of the Royal Aeronautical Society. He delivered the Wright Brothers Lecture in 1941, speaking on "New Pathways in Aeronautical Theory."

## C. C. Furnas Receives Vincent Bendix Award

The American Society for Engineering Education, at its 64th annual meeting in June, presented the Vincent Bendix Award to Clifford C. Furnas, FIAS, Chancellor of the University of Buffalo, who is now on leave to serve the United States as Assistant Secretary of Defense for Research and Development.

In making the award, the Engineering Research Council of the ASEE cited Dr. Furnas "for his personal research contributions in many fields of engineering, for his distinguished service to engineering colleges and their research activities, for publications which have served both to advance engineering science and to interpret the role of engineering college research in the future of America, for effective development and administration of university research laboratories, and for constructive efforts in advancing research policies and programs for our national defense."

## Casey Jones Honored for Training Technicians

The American Society for Engineering Education has presented its annual award for leadership in 2-year technical institute education to Charles S. "Casey" Jones, AFIAS, President of the Academy of Aeronautics, LaGuardia Airport, New York.

He received the 1956 James H. McGraw Award, a cash prize of $500, on June 26 at the Society's annual meeting at Iowa State College.

Dr. Jones was cited "for outstanding service in technical institute education, for pioneering leadership in the development of technical schools for the aviation industry, for superior administrative skills, for outstanding devotion to his country in training men for military service in aviation in both world wars, and for tireless efforts to enhance the position of the technical institute and its graduates."

**C. S. "Casey" Jones *(right)*, AFIAS, receives the James H. McGraw Award from Maynard M. Boring, President, American Society for Engineering Education.**

A pioneer aviator, Dr. Jones flew with the Aviation Section of the Army Signal Corps during World War I and then organized the Curtiss Flying Service, Inc., whose 40 schools provided the first training ground for pilots and aircraft mechanics.

During World War II, Dr. Jones helped organize the training program of the Army Air Corps. More recently, he has helped organize industry-sponsored programs to train technicians for the rapid expansion of aircraft manufacturing plants.

## Civil Service League Honors Ezra Kotcher

The National Civil Service League has presented its Career Service Award for 1956 to Ezra Kotcher, AFIAS, Technical Director of the Directorate of Development at Wright Air Development Center, Dayton, Ohio.

In 28 years of Government service, Mr. Kotcher has been closely identified with the progress of aviation as a teacher, engineer, and scientist. He holds the rank of colonel in the Air Force Reserve.

From 1928 to 1939, he was Senior Professor of Aeronautics at the Air Corps Engineering School. In 1946 he organized the USAF Institute of Technology at Wright-Patterson AFB. He was its Director for 5 years.

Mr. Kotcher took a leading part in the development of high-speed research aircraft such as the X-1, and in improving aerial refueling techniques. He headed the early Air Force program for development of guided missiles. During World War II, he headed a team of scientists who not only solved the technical secrets of the German V-1 buzz bomb but actually built and flew an American replica.

The Career Service Award was presented to Mr. Kotcher and nine other Civil Service employees at a dinner in Washington on July 2. The award consists of a scroll, personal memento, and an honorarium of $100.

## Consulting Firm Formed

Several professors, scientists, and engineers connected with Princeton University have formed a company to do research, consulting, and development work in the rocket, guided-missile, jet-propulsion, and aerodynamics fields.

Among the founders of Aerokinetics, Inc., are Luigi Crocco, AFIAS, the Robert H. Goddard Professor of Jet Propulsion at Princeton; Martin Summerfield, AFIAS, Professor of Aeronautical Engineering; J. Preston Layton, MIAS, Chief Jet Propulsion Research Engineer at the James Forrestal Research Center; and Irvin Glassman, MIAS, a Research Associate in the Department of Aeronautical Engineering.

## A Letter to the Editor

*The Review's June Editorial (depicting the "Ten Years or More" IAS staff members and entitled "The First 289 Years Were the Hardest") elicited this letter and photo from a staff member of our older "Sister Society" in England*—ED.

The Royal Aeronautical Society
With which is Incorporated the Institution of Aeronautical Engineers

Patron: Her Majesty The Queen
President: E. T. Jones, C.B., O.B.E., M.Eng., F.R.Ae.S.
Secretary: A. M. Ballantyne, T.D., B.Sc., Ph.D., Hon.F.C.A.I., A.F.I.A.S., A.F.R.Ae.S.

4 HAMILTON PLACE
LONDON, W1

Telephone: Grosvenor 3515-19

Ref:FHS/AB/383/I

2nd July 1956

Welman A. Shrader, Esq.,
Director of Publications,
Aeronautical Engineering Review,
2, East 64th Street,
New York, 21.

Dear Shrade,

I was delighted to see the fossils foto in the Aeronautical Engineering Review which we have just received. As a matter of interest, I have dug out a snap of our older members of staff which I enclose herewith. Extreme front, Bill Huggins (1901) behind him Fanny Digwort (1889). Left to right, back row Susie Slaptickle (1903), Maggie Dinkwall (1898), Polly Patchett (1908) and Jim Stenchback ( just after the Boer War when he had the back of his head blown off). The instrument on the left is the Society organ - now known as the Journal. The photo over the organ is of Turbulent Flo, the current Society toast.

Yours,

Frank

F.H.SMITH
LIBRARIAN

## Necrology

### Carl Dienstbach

Word has been received of the death of Carl Dienstbach, MIAS, on June 27 in Usingen, Germany. He was 86 years old.

Mr. Dienstbach, an inventor and writer, lived in Astoria, Long Island, N.Y., but returned to his home town in Germany several months ago after many years' absence.

Mr. Dienstbach had been a member of the Institute since 1944.

### Joseph J. Hill

Joseph James Hill, TMIAS, of St. Charles, Mo., died on June 5. He was 42 years old.

Mr. Hill was employed as an engineer by McDonnell Aircraft Corporation.

## Lear Engineering Scholarship

The William P. Lear Foundation, Inc., of Grand Rapids, Mich., has given an engineering scholarship grant to the University of Michigan.

The Foundation suggested the award be used to further the education of a needy but deserving student majoring in aeronautical engineering or specializing in electronics as applied to the aircraft industry.

## NEWS OF MEMBERS

▸ **Don K. Covington, Jr.** (M), Sales Manager of The Harbor Sales Company, Inc., has been elected Vice-President of the Sales Executives' Council of the Baltimore Association of Commerce.

▸ **John W. Hoover** (M), Associate Professor of Aeronautical Engineering at the University of Florida, has been elected Chairman of the Aeronautical Division of the American Society for Engineering Education.

▸ **Lt. Col. Richard L. Long, USA** (TM), was graduated in June from the regular 10-month course at the Command and General Staff College at Fort Leavenworth, Kan. He has been assigned to the Transportation Supply and Maintenance Command at St. Louis, Mo. Colonel Long is an Army aviator with multiengine, instrument, and helicopter ratings.

▸ **Eugene J. Manganiello** (AF), Assistant Director of the NACA's Lewis Flight Propulsion Laboratory, has been elected Vice-Chairman of the Cleveland Section of the Society of Automotive Engineers.

***Members on the move . . . .***

*This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.*

**Waldemar O. Breuhaus** (M) has been promoted to Head of the Flight Research Department of Cornell Aeronautical Laboratory, Inc.

**Hans Eckert** (M), formerly a senior aerodynamics engineer on missile projects at Convair, San Diego, A Division of General Dynamics Corporation, has been transferred to Convair's Department of Scientific Research.

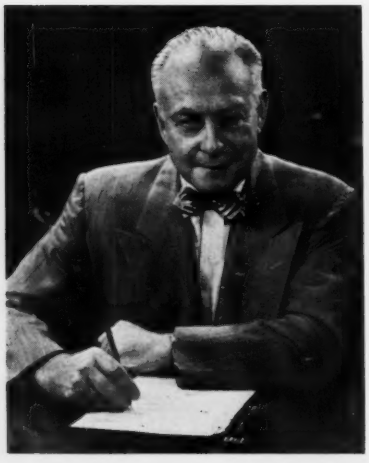
**Kenneth M. Foreman** (TM) has joined Fairchild Engine Division, Deer Park, N.Y., as a research engineer in the Research and Advanced Engineering Department. He was formerly a project engineer and section head for ram-jet development engineering with Wright Aeronautical Division of the Curtiss-Wright Corporation.

**Edward E. Foster** (AF), former Head of the Engineering Design and Shops Department of Cornell Aeronautical Laboratory, Inc., has been promoted to Program Coordinator in the office of the Assistant Director—Technical.

**Duncan Gardiner** (M), formerly Assistant Chief Engineer, has been named Director of Research and Development of Vickers Incorporated. He joined the Detroit firm in 1934.

**Oscar E. Holt** (M) has been promoted to Manager of the W. L. Maxson Corporation plant at Old Forge, Pa.

**J. H. "Dutch" Kindelberger, an Honorary Fellow of the Institute and Board Chairman of North American Aviation, Inc., has been awarded the honorary degree of Doctor of Engineering by Carnegie Institute of Technology.**



**Harry F. Vickers, MIAS, President of the Sperry Rand Corp. and founder of Vickers Incorporated, received an honorary Doctor of Science degree from the University of Southern California on June 9. He was the Commencement speaker.**

**George L. Haller, AFIAS, has been named General Manager of the new Defense Electronics Division of General Electric Co. in Syracuse, N.Y. He formerly headed the Laboratories Department.**

**Otto J. Kolb** (M) has been promoted to Chief Product Engineer in the Avionic Engineering Division of General Precision Laboratory, Inc.

**John J. Konikoff** (M), formerly Chief Development Engineer of Thermal Research and Engineering Corporation, has joined the Special Defense Products Department of General Electric Company, Philadelphia.

**Clifford M. Larson** (AF) has retired after 37 years with Sinclair Refining Company, New York, and has entered private practice as a Consulting Engineer at Larcliff, 55 Taymil Road, New Rochelle, N.Y. Formerly Sinclair's Chief Consulting Engineer, he served as consultant to the Secretary of War on fuel and lubricant problems during World War II.

**Henry F. McKenney** (M) has been elected Vice-President for Engineering of Electronics Corporation of America, Cambridge, Mass. Previously, he was Chief Engineer of the Ford Instrument Company Division of Sperry Rand Corporation.

**William F. Milliken, Jr.** (M), has been named Director of the newly formed Full-Scale Division of Cornell Aeronautical Laboratory, Inc. This Division was formed by consolidating the Flight Research Department, which he formerly headed, with the newly created Vehicle Dynamics Department.

**Nathan M. Newmark** (M), Research Professor of Structural Engineering at the University of Illinois, has been named Head of the Civil Engineering Department. Dr. Newmark, a former member of the USAF Scientific Advisory Board, also is Chairman of the Digital Computer Laboratory of the Graduate College.

**Gaylord W. Newton** (M) has been appointed Manager of Applications Engineering in the Aircraft Nuclear Propulsion Department of the Aircraft Gas Turbine Division, General Electric Company, Cincinnati. He was formerly Chief of the Engine Test Facility operated by ARO, Inc., at the Air Force's Arnold Engineering Development Center, Tullahoma, Tenn.

**Harner Selvidge** (M) has been appointed Staff Engineer for the Western Divisions of Bendix Aviation Corporation. He has been transferred to North Hollywood, Calif., from Detroit, where for the past 10 years he has been Director of Special Products Development.

**Merwin Sibulkin** (M), formerly a research engineer with the Jet Propulsion Laboratory of California Institute of Technology, has joined the Scientific Research Staff of Convair, A Division of General Dynamics Corporation, in San Diego, Calif.

**John D. Stanitz** (M) has been promoted to Chief Engineer of the Accessories Division of Thompson Products, Inc., Cleveland.

**Merritt A. Williamson** (M), former manager of the Research Division of The Burroughs Corporation, has been named Dean of the College of Engineering and Architecture at The Pennsylvania State University. He has been a special lecturer on Research Administration at the University of Pennsylvania.

## CORPORATE MEMBER NEWS

• **Aerojet-General Corporation**...A $13,000,000 manufacturing building under construction at the Sacramento (Calif.) plant will be used for production of liquid-propellant rocket engines for the USAF Air Materiel Command. The new building will have 360,000 sq.ft. of manufacturing space. . . .An Aerobee-Hi sounding rocket set a new record of 163 miles at White Sands, N.M., on June 29, according to a Navy announcement. Martin's Viking rocket held the previous altitude record of 158 miles. The Aerobee-Hi carried 130 lbs. of instruments and had a gross weight of about 1,500 lbs. In the course of a decade, according to the company, more than 150 Aerobee rockets have been built, and their performance record was 89 per cent successful. Aerojet-General is now building 68 Aerobees and Aerobee-Hi's which will be used for upper atmosphere research by the Air Force, Navy, Army Signal Corps, and other scientific agencies during the International Geophysical Year, 1957–1958.

• **Aeroquip Corporation,** of Jackson, Mich., offers a new booklet analyzing different designs of self-sealing couplings.

• **Airborne Instruments Laboratory, Inc.** ...The Inchworm Motor is a linear actuator developed by A.I.L. to fill the need for a powerful feed mechanism that is accurately controllable in the range of microinches. It is a logical successor to the lead screw in all mechanisms requiring microinch (0.000,005 in. to 0.0001 in.) dimensional control. It has found its first large-scale application in the machine tool field, replacing the lead screws in centerless grinders producing precisely finished hydraulic components. The name derives from its method of operation. The Inchworm actually creeps along in microinch steps, expanding and contracting. Employing the magnetostrictive effect, the armature of the motor shrinks under the influence of an electromagnetic field but snaps back to original size when the magnetic field is de-energized. The Inchworm actuator has brought the stick-slip problem under control. The company claims the Inchworm Motor promises to revolutionize a large portion of the metals-working industry in which precise fit requirements have, for many years, demanded selective mating of components to compensate for machining inaccuracies. The components can now be manufactured to the precise dimensions required. Elimination of the selective fit requirement opens the door to automatic assembly.

• **Allis-Chalmers Manufacturing Company,** of Milwaukee, Wis., has issued a bulletin on "End-Shield Bearing Synchronous Motors."

• **Allison Division, General Motors Corporation**...A brochure has been issued on "Development of the Allison Turboprop Engine for Air-Line Use." Aeroproducts Operations, Dayton, Ohio, has issued a brochure on "Actuators for Aircraft."

**Produced in the Air Force plant at Alcoa's Cleveland Works, this closed-die forging of aluminum alloy weighs 3,000 lbs., is 156 in. long, 36 in. wide, and 12 in. thick.**

• **Aluminum Company of America**...What is believed to be the largest closed-die forging ever made has come from the Air Force's giant 50,000-ton press at the Alcoa plant in Cleveland. It is an aluminum-alloy air-frame part 13 ft. long, 3 ft. wide, and 1 ft. thick. It weighs 3,000 lbs. The king-size forging was manufactured for The Glenn L. Martin Company for use in the air frame of the XP6M SeaMaster. It will form part of the backbone of the fuselage and wing structure of the huge four-jet seaplane. Engineering and production of the 60-ton set of steel dies required several months, with sinking and finishing operations for each die consuming 1,500 man-hours.

• **Bell Aircraft Corporation** has pledged financial aid in the amount of $75,000 for the construction of a nuclear research center at the University of Buffalo. The University expects to break ground November 1 for the $750,000 project.

• **Bendix Aviation Corporation** announces that Canadian rights to the manufacture and sale of the Bendix-Decca navigator system, now in use in an area 1,500 miles long across Europe, have been licensed to its Pacific Division. Bendix-Eclipse of Canada, Ltd., is associated in the licensing agreement. The Canadian Army and Air Force conducted a test of the Bendix-Decca system recently. The system has been adopted by the Canadian Hydrographic Office, primarily for operations off the East Coast. A brochure on "The Bendix-Decca Navigator System" may be obtained from Bendix Pacific Division, North Hollywood, Calif.

• **Boeing Airplane Company**...In 1959, when the Boeing 707 jet air liner enters commercial service, it will be possible to fly around the world in 40 hours with only

(*Continued on page 72*)

# AVIATION CHALLENGES YOU

## As Tomorrow's Engineer...

## ...WHAT SHOULD YOU BE LIKE?

So far, so good. We have indicated the historic growth and challenging future of the aviation industry. We have shown that the engineer is the key man in aviation, and we have said that the engineer possesses certain qualities and has had intensive training.

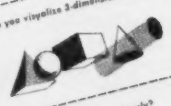
You want to be an engineer. You have the necessary qualities. How do you get the training? The following pages will give you some considerations essential in planning for your engineering education.

### YOU HAVE THESE TRAITS?

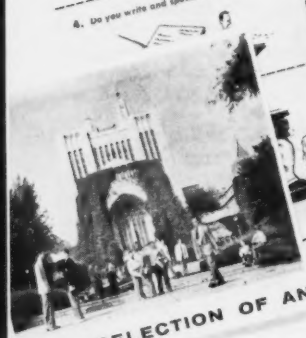
ous about why things work?

2. Interested in Math and Science?

3. Can you visualize 3-dimensional shapes?



4. Do you write and speak clearly?



Electronic Component Studies

## PLANNING FOR YOUR ENGINEERING EDUCA

MOST ENGINEERING COLLEGES require that entrants shall have co following subjects:

| | |
|---|---|
| Algebra | Trigonometry |
| Plane Geometry | English |
| Solid Geometry | Mechanical Drawing |

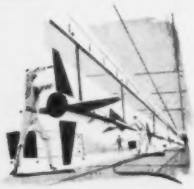
Entrance requirements usually specify a minimum "B" average in them in one or two of these requirements are obliged by some engineering schoo Qualifications for entrance will, of course, differ from one college to anothe

Catalogs are easily obtained from individual colleges free of charge and You are urged to get copies from the

If you are

## YOUR SELECTION OF AN ENGINEERING COLLEGE

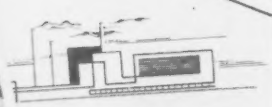
...ion of an educational instit



## After Graduation

## ...YOUR PROFESSIONAL LIFE

...ic career in aviation moves ahead another ...You will then give much detailed ...loing to your education ... select your college ... nd best suit your a... e the following ... rofessional en... our comm...



...is the design and construction of ...th the air. Manned vehicles range ...copters to gigantic multi-ton bombers and ... professional men — lawyers, doctors, ...

...RN UP-TO-DATE FACILITIES

## ...OUR EMPLOYERS IN AVIATION

basic product of ...

...IANA
...siana Polytechnic Institute—Ruston
...siana State University—University
...ne University—New Orleans
...NE
...versity of Maine—Orono
...YLAND
...ns Hopkins University—Baltimore
...versity of Maryland—College Park
ASSACHUSETTS
...arvard University—Cambridge
...assachusetts Institute of Technology—Cambridge
...assachusetts—Lowell
...Northeastern University—Boston
...Tufts College—Medford
...University of Massachusetts—Amherst
...Worcester Polytechnic Institute—Worcester
...Worcester Junior College
MICHIGAN
...Michigan College of Mining and Technology
...Michigan ...

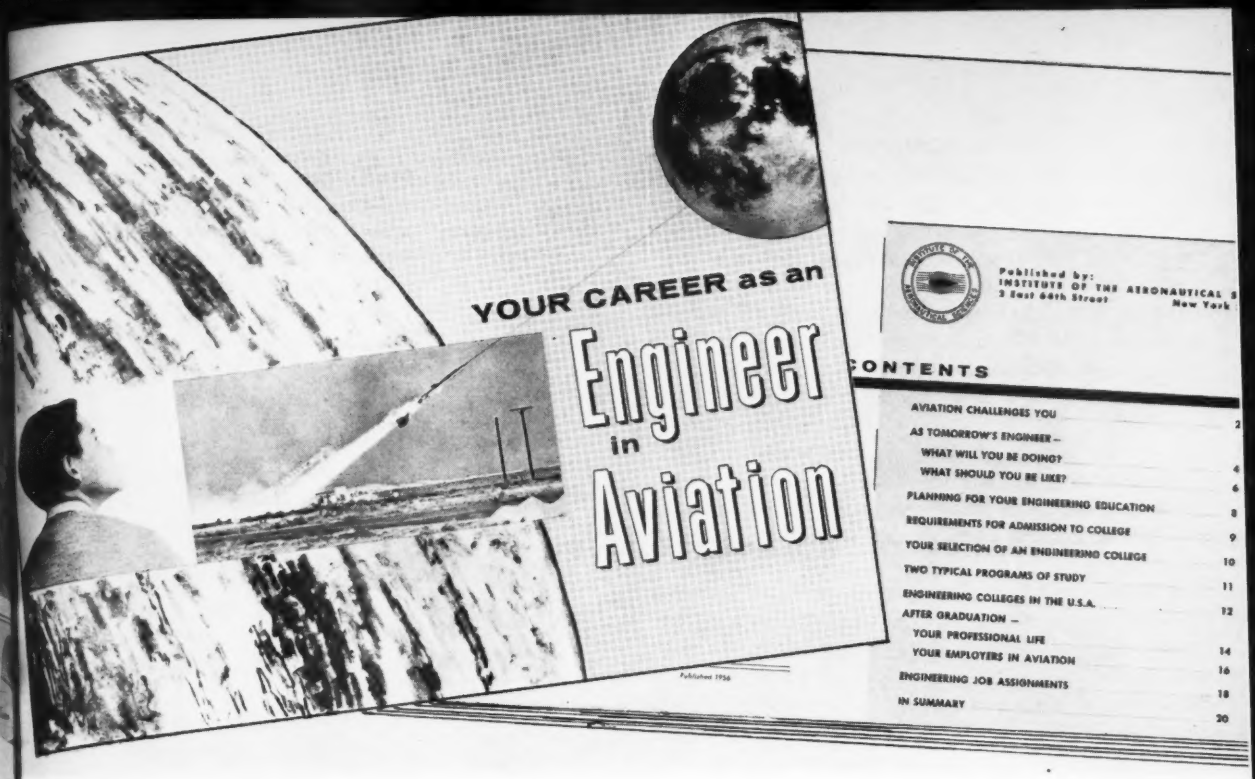
## TWO TYPICAL PROGRAMS OF STUD

The programs shown are examples of a ... program on the left is a 4-year "basic engi... aeronautical engineering at the beginning ... curricula vary widely within the limits ... student considerable choice in his progra...

The choice of a specialty as "major" field ... man year, when the student has become ...

Basic Engineering

Freshman Year
Orientation Period




# *Editorial*

## Progress Report—Vocational Guidance

It is no news to members of this Institute that we have had a longtime interest in the problem of educating more and better aeronautical engineers. REVIEW readers will remember the statement made by the then IAS President, Wellwood Beall, of Boeing, in his Editorial in the April, 1952, issue. He pointed out that there could be no better program for the IAS than "to bring about a renewed interest in aeronautical engineering as a promising and challenging profession."

Six months later (REVIEW, October, 1952) we announced editorially the first stage in our vocational guidance plan—the publication of an IAS VOCATIONAL GUIDANCE MANUAL. This booklet was titled *A Guide to the Engineering Profession in the Aviation Industries.* During the following 3 years it went through two editions and over 60,000 were distributed through industrial and educational channels. Intended to be a source book of information for vocational guidance advisers in high schools and colleges, it has served its purpose well, as attested by a continuing demand for copies (a third edition is now in preparation).

Now the IAS has taken one further step in the program. For the first time we have addressed the potential student directly, urging him to consider the advantages of an engineering education in general and of an aeronautical education in particular. The new booklet *Your Career as an Engineer in Aviation* has just come from the presses and the first distribution is under way. Sufficient funds to provide for the preparation of the booklet and for an initial printing of 50,000 were authorized by the Council some months ago.

We realize that this number of copies is far short of the requirement to place one of these booklets in the hands of every high school student in the U.S. The distribution plan, carefully worked out by our staff after a long-range study of the situation, contemplates placing 3 or 4 copies in the hands of secondary school vocational advisers in the 12,000-odd secondary schools with 300 or more students. They can there be made available to those most interested without the excessive wastage that a "shotgun" type of distribution would inevitably incur.

We anticipate that the eventual demand for this booklet will far and away exceed the budgetary capabilities of the IAS. We hope, however, that the several elements of the industry who are vitally interested in the problem will see enough merit in the project to make a much larger distribution possible. This matter has already been called to the attention of our Corporate Members.

Credit for this publication goes to the Students Activities Program of the IAS. Thomas Meskel, Assistant IAS Secretary, and Paul Welles of his staff did an outstanding job in organizing and developing the material. They were ably assisted in the layout, production, and publication phases by Hugh Judge, who is generally responsible for the quality of presentation in all IAS publications. We are all proud of this effort. We consider it another long step forward in carrying out one of our prime responsibilities to the industry that we serve.

S. P. J.

*With considerable vision, the author concludes that a properly proportioned rocket-propelled airplane may be developed which will carry cargo over stage lengths of several thousand miles at a direct flying cost of less than 10 cents per ton-mile and at an average flight speed of about 5,000 m.p.h.*

# Economics of Rocket-Propelled Airplanes—Part I*

Robert Cornog†
The Ramo-Wooldridge Corporation

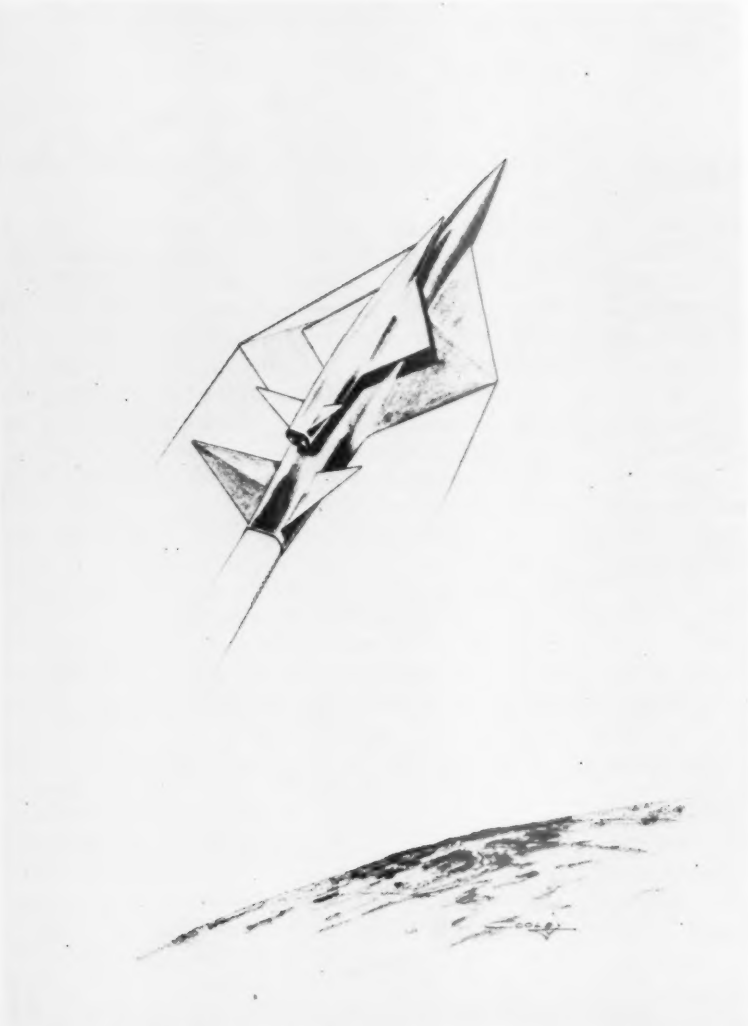


FIG. 3-1. Conceptual embodiment of two-stage rocket vehicle.

(I) ABSTRACT

Consideration is limited to recoverable vehicles which are man carrying and which resemble conventional airplanes in many respects. For such rocket-propelled aircraft, the primary factor which determines the cost of delivering a load to a destination is the cost of the propellants consumed.‡

Propellant consumption may be minimized by adopting a flight program in which the airplane is initially accelerated to high speed and then glides to the destination.

For most of the cases considered, liquid oxygen and a hydrocarbon oil (gasoline, kerosene, etc.) form the cheapest chemical propellant combination from the standpoints of cost per unit weight of the propellant mixture and of propellant cost per ton-mile of cargo transported.

(*Continued next page*)

* Attention is invited to the unusual number of papers in this Roster Issue of the REVIEW. Many factors have made this possible, one being the kind permission of the author to continue his paper over to the October issue. References used by Dr. Cornog will appear customarily at the end of his paper.

† Member of the Technical Staff, Guided Missile Research Division.

‡ By way of contrast, if a nonrecoverable vehicle is used to deliver a load to a destination, it will be found that the cost of the structural parts of the vehicle, which must be included in the total delivery cost, is the dominant factor in determining the total delivery cost.

The rocket-powered airplanes investigated and described in this study are "paper" airplanes. Before they can be converted from phantasmagoria into practical, operational vehicles, several key requirements must be met. The two most important of these key requirements are: (1) Aerodynamic lift/drag ratios of the order of four or more must be obtained at flight speeds in the range of Mach 10 to Mach 16.* (2) Structural factors must be achieved such that the initial gross weight of an airplane is at least four times its empty weight.

## (II) Introduction

In most parts of the world it is cheaper to buy, maintain, and service an oxcart than it is an airplane. In spite of this fact, there are more airplanes than oxcarts in most civilized areas of the world. The key to this paradox is the relative speed of transportation afforded by each vehicle.

The gross revenue or income which the operator of a transportation system receives is, in almost every case, directly proportional to the amount of service rendered. Thus, the operator of an air line receives so much per ton-mile or passenger-mile of pay load transported. An obvious way to increase the operating profit in a given air line (with a fixed number of airplanes) is therefore to maximize the gross income. This can be done by:

(a) Operating all the equipment as much as possible. Thus, each airplane should fly at maximum loading and the maximum possible number of hours per day. In this manner, the number of ton-miles or passenger-miles for which payments are received is maximized.

(b) Flying at high speed. Other things being equal, if an airplane flies twice as fast, it will bring in twice as much revenue.

The factors grouped under (a), above, are usually not completely under the control of the air-line management. Even with the best of planning, flight loading is a variable market factor which changes with the ebb and flow of economic tides. The utilization of flight equipment is currently limited by the set of regulatory laws and rulings formulated and promulgated by the government or governments involved. In this country the CAA and CAB regulate air traffic.

The maximum flying speed for a given aircraft, see (b), above, is limited. Usually the fuel consumption and cost increase sharply as the flying speed is increased. In practice, there is usually an optimum operating speed for a given airplane. At this speed, the increased revenue obtainable by flying still faster exactly balances the increased fuel cost. In practice, this speed is usually about one and one-half times the flight speed at which minimum fuel consumption is obtained.

The operational characteristics of an airplane at the optimum operating speed, as outlined in the foregoing, is a most important factor to the designer of commercial aircraft. It is the most tangible yardstick used by air-line managements in evaluating all new airplanes. In a free economy, the strongest incentive for the air-line management to replace existing airplanes with newer and more expensive models is the expectation that the change will increase the net profit.

Other factors being equal, the faster the flight speed of a transport air liner, the faster it produces passenger-miles or ton-miles of potential revenue. Alert airplane designers are well aware of this fact. It is this economic incentive for higher flying speeds which is primarily responsible for the steady increase in the flying speeds of commercial air liners.

At supersonic flight speeds, the aerodynamic efficiency of airplanes is much less than at subsonic speeds. In other words, the aerodynamic drag which must be overcome in order to maintain an airplane of a given weight at fixed speed in straight and level flight is much greater. There are valid reasons for believing that this increased drag penalty incurred by flying at supersonic speeds is a fundamental one and that it is highly probable that the lift/drag ratio of subsonic aircraft will always be better than the lift/drag ratio of supersonic aircraft.

If the increased fuel consumption occasioned by the increased aerodynamic drag at supersonic flight speeds can be more than compensated for by the increased rate at which the supersonic airplane produces revenue, there exists a sound economic motive to develop supersonic aircraft for commercial transport application. Several studies have been made to attempt to find an answer to this question. For the most part, these studies have been confined to conventional turbojet-powered planes flying at speeds in the region of Mach 1.5 to Mach 2.5 and at altitudes in the region of 40,000 to 65,000 ft.

A much more challenging and stimulating line of thought may be initiated if the economic incentives for high flight speeds, as described above, are exploited to the hilt. In other words, let us consider flight at the highest possible speed and ask ourselves the following questions: What are the costs of operating such aircraft? and how do the revenue-producing potentialities of such aircraft compare with those of aircraft flying at lower speeds? A study of these two questions constitutes the body of this report.

Approximately 20 years ago, detailed designs for rocket-driven airplanes were proposed in which satellite velocities were to be obtained.[1] The flight speed of such a vehicle is approximately 15,000 m.p.h.—i.e., 30 to 50 times the 300- to 500-m.p.h. flight speed of existing commercial aircraft.

It has been assumed throughout this study that all the technical problems associated with the development, construction, and operation of a commercial rocket-powered airplane have been successfully mastered and that such a rocket-driven airplane, moving at near satellite speeds, has been adapted to commercial air-transport use. Before one can correctly assert that such a rocket-powered satellite vehicle is the ultimate in high-speed commercial transport design, it must be

* This requirement may be somewhat relaxed for rocket airplanes designed and used for ranges in excess of 6,000 miles. (See "Propellant Costs" and "Necessary Assumptions," the latter in Part II.)

TABLE 3-1. DESCRIPTION OF ROCKET-PROPELLED AIRPLANES

| | | | |
|---|---|---|---|
| **GENERAL** | | | |
| Range<br>Propellants<br>Structural Factor | 5740 miles<br>oil and $O_2$<br>0.10 | 5740 miles<br>oil and $O_2$<br>0.10 | 5740 miles<br>oil and $O_2$<br>0.15 |
| **WEIGHT BREAKDOWN** (All Weights in Pounds) | | | |
| Load Carrying Stage | | | |
| Maximum Payload<br>or No. of Passengers<br>Propellants<br>Structure | 10,000<br>(50)<br>30,050<br>4,450 | 10,000<br>(50)<br>62,000<br>8,000 | 10,000<br>(50)<br>103,000<br>20,000 |
| Total Initial Weight | 44,500 | 80,000 | 133,000 |
| Launching Stage (Rocket) | | | |
| Payload<br>Propellant<br>Structure | 44,500<br>133,700<br>19,800 | | |
| Total Initial Weight | 198,000 | | |
| Lifting Stage (Turbojet Power) | | | |
| Payload<br>Engines<br>Other Structure<br>Fuel | | 80,000<br>7,000<br>5,000<br>25,000 | 133,000<br>11,000<br>8,000<br>45,000 |
| Total Take-off Weight | | 117,000 | 197,000 |
| **FUEL & PROPELLANT COSTS** | | | |
| Thousands of ton miles/trip<br>Propellant cost, cents/lb<br>Turbojet fuel cost, cents/lb | 28.8<br>0.887 | 28.8<br>0.887<br>2.0 | 28.8<br>0.887<br>2.0 |
| Total propellant cost - kilocents/trip | 145 | 54.9 | 91.5 |
| Total jet engine fuel cost - kilocents/trip @ 2¢/lb | none | 50 | 90 |
| Total cost of expendable chemicals - kilocents/trip | 145 | 105 | 182 |
| Total fuel cost, cents/ton mile | 5.03 | 3.64 | 6.32 |

shown that no other type of vehicle (i.e., nonrocket) will fly as fast and that no other rocket-powered vehicle will fly faster.

It can be shown in a variety of ways that air-breathing engines cannot be made to fly much faster than Mach 8. This upper bound is a fairly sharp one. Aerodynamic heating becomes an insuperable problem in air-aspirating engines designed for higher flight speeds. The writer is not able to visualize engines other than rocket engines which will operate in a vacuum.*

At flight speeds higher than satellite speeds, the centrifugal force on a vehicle, tending to throw it off into space, is greater than the gravitational attraction of the earth. Consequently, a vehicle traveling at these speeds must fly "upside down" in the atmosphere and utilize the negative aerodynamic lift thus developed to keep the vehicle within the atmosphere. The drag engendered by such a procedure varies as the square of the increase in flight speed. Since the increase in revenue varies only as the first power of the increase in flight speed, it is apparent that a speed must soon be reached at which the drag losses are prohibitive.†

It is concluded, therefore, that with the possible exception of cargo capsules moving in an evacuated tube, no other form of terrestrial transportation can or will move faster than rocket-propelled airplanes.

* The electrodynamic acceleration of incapsulated vehicles traveling in evacuated tubes on the surface of the earth constitutes an important exception. The properties of such transportation systems have been discussed elsewhere.[5]

† A few years ago a spokesman for a large airplane manufacturer predicted that flight speeds of 186,000 m.p.h. would be attained. At these speeds, passengers on an earth-bound vehicle would be subjected to negative accelerations of more than 100g.

## (III) General Properties of Rocket-Propelled Airplanes

### *(A) Optimum Flight Program*

It will be found that the best—i.e., most economical—flight procedure of rocket-powered aircraft is very different from any contemporary airplane. The energy in the propellants can be used most effectively if the airplane is brought to maximum speed immediately after take-off. The airplane then glides at great altitude and high speed toward its destination.

The gliding portion of the flight is very different from ordinary gliding. Assuming still air, there is a constant loss of altitude in ordinary gliding flight. The force required to overcome the aerodynamic drag is obtained at the expense of gravitational potential energy. In the rocket airplane, however, the work required to overcome aerodynamic drag is obtained primarily at the expense of the kinetic energy of the airplane. Consequently, there is a continuous decrease in velocity during the gliding portions of the flight.

The rocket airplane will also lose altitude during the gliding portion of flight. However, the energy thus obtained is only a few per cent of the kinetic energy initially available. The loss of altitude follows from the requirement that, in order to maintain an optimum lift/drag ratio and the necessary lift, the ambient air density must be increased as the velocity decreases. (In other words, the airplane is piloted to lower altitude where the density of the air is greater.) This type of gliding is frequently called "momentum gliding" and has been described by several authors.[2, 3, 4]

In order to permit clear comparison between rocket-propelled aircraft and other types of transportation, there follows a description of the construction and operation of the rocket-propelled aircraft whose economic characteristics are to be investigated.

It has been assumed that, in every case, the designer has attempted to evolve a design which will render the desired transportation at the minimum possible cost to the air-line operator. It has been further assumed that existing chemical propellants must be used. The potentialities of nuclear-powered aircraft are discussed in Appendix 3 of Part II.

A two-stage rocket vehicle is assumed. A possible embodiment is shown in Fig. 3-1 (see p. 30). Wing loading of both stages, in the empty condition, will be somewhere in the range of 10 to 100 lbs./ft. Thus, the landing speeds and landing runway requirements are no different from contemporary aircraft.

Launching technique and general program of flight are very similar to those suggested by Sänger[1] and Thiel.[3] The completely loaded vehicle is launched from a recoverable rocket-propelled sled or dolly. The larger stage completes its burning and acceleration in about 3 or 4 min. Immediately thereafter the smaller stage continues acceleration for an additional 3 or 4 min. At the end of the acceleration period, the smaller residual stage is traveling at a velocity of approximately 16,000 ft./sec. At this speed, an appreciable

fraction of its weight is supported by centrifugal forces. The remainder is supported by aerodynamic forces in a conventional manner. The initial flight altitude is approximately 35 miles and decreases slowly during the flight. The time required to reach the destined airport is approximately 40 min.

The large stage, used only during the initial acceleration period, performs a gliding turn and coasts back to the airport where it will be available for other launchings. While this unit may be piloted, its role may be clarified if it is considered to be an unusually elaborate, recoverable, rocket-assisted take-off unit.

Under some circumstances, it will develop that only a single-stage rocket is necessary. In other words, the rocket-assisted take-off unit is not always necessary.

#### *(B) Properties of Three Specific Designs*

Some of the more important properties of three possible rocket airplane designs are given in Table 3-1. A discussion of most of the assumptions used will be found in the pages which follow. There is nothing especially significant in the designs selected.

### (IV) Direct Flying Cost of Rocket Aircraft

#### *(A) Economics of Air-Line Operation*

In order to permit meaningful comparisons, students of air-line economics have adopted certain conventions in tabulating the operating costs. A description of these conventions follows. It is hoped that a short exposition of this discipline not only will aid in understanding the probable costs of the operation of rocket-propelled aircraft but will also help focus attention on the probable economic factors which affect the evolution of current and expected future transport aircraft.

Ordinarily, the costs of operating a commercial air line are divided into two broad categories—direct flying costs and overhead or burden. A third category, profit, is sometimes lumped with direct flying costs and is sometimes considered as a separate category.

*Direct Flying Costs*—The category called direct flying costs usually includes:

(1) The fuel and oil consumed during flight.
(2) Interest on capital invested in flight equipment.
(3) Depreciation on the airplane.
(4) Cost of overhaul, repairs, and maintenance on the airplane.
(5) Insurance and taxes on flight equipment.
(6) The salaries of flying personnel.

Both the individual component costs and the total direct flying costs vary from year to year, from air line to air line, and between one plane and another. However, Table 4-1 is believed to be representative of contemporary commercial air-line operation in the United States.

*Application to Rocket Airplanes*—In order to compute the direct flying costs of rocket-propelled airplanes, Table 4-1 has been modified as follows:

Table 4-1

| | Contemporary Air-Liner, % | Rocket-Powered Transport, % |
|---|---|---|
| (1) Fuel and oil | 28 | 80 |
| (2) Interest on investment | 5 | 1 |
| (3) Depreciation | 24 | 6 |
| (4) Maintenance and repair | 24 | 9 |
| (5) Insurance and taxes | 7 | 1 |
| (6) Flight payroll | 12 | 3 |
| Total | 100 | 100 |

(1) *Fuel and oil:* The cost of propellants burned in the rocket corresponds to the fuel and oil consumed in the conventional airplane.

(2) *Interest on investment:* The operator of a rocket airplane must pay interest to the agency from which he borrowed money to pay for the airplane. Alternatively, if the operator had the capital himself, he loses the interest he could have received on his money had he not bought the airplane.

(3) *Depreciation:* After a period of use, the airplane will be obsolete and valueless. The prudent operator will set aside funds at a rate adequate to compensate for this loss.

(4) *Maintenance and repairs:* In order to keep the airplane in a safe operating condition, periodic repairs and maintenance work must be performed.

(5) *Insurance and taxes:* Flight equipment will be taxed and should also be insured against inadvertent loss or damage.

(6) *Flight payroll:* Salaries of all flight personnel are included in this category.

*Overhead Costs*—In addition to the direct flying costs, there are a number of indirect costs which are usually lumped together to form what is known as burden or overhead. Included in the burden costs are rents and other costs of maintaining airport facilities, salaries of ticket agents and other sales personnel, advertising costs, and administrative and legal expenses.

In general, the burden is approximately 80 per cent of the direct flying costs. It should be noted, however, that since the burden is an insensitive function of the type of airplane being used, any reduction in the direct flying costs increases the relative costs of the burden.

It is worth pointing out that the burden cost per ton-mile of service delivered is reduced when the length of flight is increased. The longer flight entails approximately the same amount of overhead activity yet produces more ton-miles of revenue than a short flight. It will be shown that in most cases the direct flying costs of rocket airplanes also decrease as stage length is increased (see Fig. 4-2). It may be concluded, therefore, that rocket airplanes will be most economical (and most competitive with conventional airplanes) when used between cities which are several thousand miles apart and which are situated so that no facilities can be installed for refueling conventional airplanes at intermediate points.

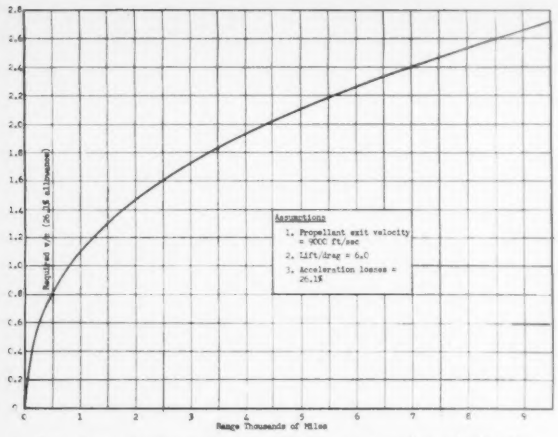



FIG. 4-1. Acceleration requirements of rocket airplanes.

### *(B) Propellant Costs*

(1) *Velocity Requirements—*

(a) *Range of a momentum glider:* In order to compute the cost of transportation when using rocket-propelled airplanes, numerical values must be assigned to several performance parameters. One of the most important of these is the lift-to-drag ratio. It can easily be shown that the range of a momentum glider having an initial velocity, $v_0$, ft./sec. is[5]

$$S = (R/2)\,(L/D)\,\log_e\,[1 - (v_0^2/Rg)]^{-1} \qquad (1)$$

where

$S$ = range (ft.)
$R$ = radius of earth (ft.)
$L/D$ = lift/drag (assumed constant)
$v_0$ = initial velocity (ft./sec.)
$g$ = gravitational acceleration (ft./sec.$^2$)

It was assumed throughout all computations that the average lift/drag ratio to be used in this equation is 6. This is a crucial assumption, especially in cases where the velocity $v_0$ is appreciably smaller than the satellite velocity. Some experimental results showing lift/drag ratios of more than 7 at Mach 7 are given in reference 8. Sänger has pointed out that, for configurations designed for hypersonic speeds, the lift/drag ratio will ordinarily improve as the flight speed is increased. Pertinent material may be found in references 4 and 12.

Table 4-2 was obtained by substituting $L/D = 6$ in Eq. (1).

(b) *Acceleration allowance:* In a gravity-free vacuum, called the ideal condition, the terminal velocity $v$ of a rocket airplane, starting from rest, is[8]

TABLE 4-2

| Initial Velocity, ft./sec. | Glide Range, miles |
|---|---|
| 5,000 | 420 |
| 7,000 | 825 |
| 12,000 | 2,880 |
| 16,000 | 5,740 |
| 20,000 | 10,820 |

$$v = \sum_{i=1}^{n} c_i \log_e \left(\frac{M_{0i}}{M_i}\right) \qquad (2)$$

where

$c_i$ = effective exhaust velocity of the $i$th stage
$M_{0i}$ = initial mass of the $i$th stage
$M_i$ = final mass of the $i$th stage
$n$ = number of stages in the rocket

The formula does not give the complete story. In addition to the acceleration to maximum velocity, the rocket-propelled airplane must climb to the top of the atmosphere. Because of the amazingly small ratio of the air density at flight altitude to the density at sea level (roughly 1 to 1,000), the rocket-powered airplane is forced to fly very slowly during the early portions of its climb. Rocket engines are very inefficient when operated at low speed. Consequently, appreciable quantities of propellant must be "wasted" in pushing the rocket up through the denser portions of the atmosphere.

The *acceleration allowance* is the percentage by which the ideal velocity obtained by the preceding equation must be increased to cover the aerodynamic and gravity losses encountered during the acceleration of an actual rocket-powered airplane.

If viewed in this manner, the use of a special power plant during the climb through the atmosphere suggests itself. For example, if a lightweight turbojet* is used to lift the rocket-powered airplane to an altitude of 100,000 ft., an enormous amount of propellant can be saved and used more efficiently during the later, high-speed portion of the acceleration process.

* In *Aviation Age*, p. 18, April, 1955, A. G. Elliott of Rolls-Royce is stated to imply that "lift engines could be developed having a specific weight of 0.01, or even better."

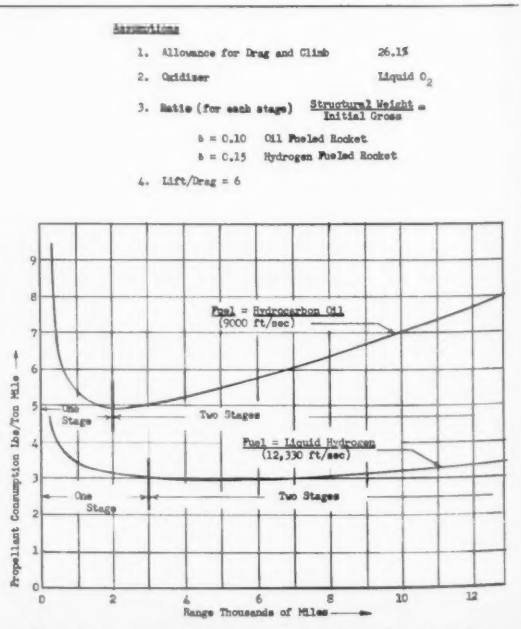

Assumptions
1. Allowance for Drag and Climb 26.1%
2. Oxidiser Liquid O2
3. Ratio (for each stage) Structural Weight / Initial Gross
b = 0.10 Oil Fueled Rocket
b = 0.15 Hydrogen Fueled Rocket
4. Lift/Drag = 6
Fuel = Hydrocarbon Oil (9000 ft/sec)
Fuel = Liquid Hydrogen (12,330 ft/sec)
One Stage
Two Stages
Propellant Consumption lbs/Ton Mile
Range Thousands of Miles

FIG. 4-2. Propellant consumption in rocket aircraft.

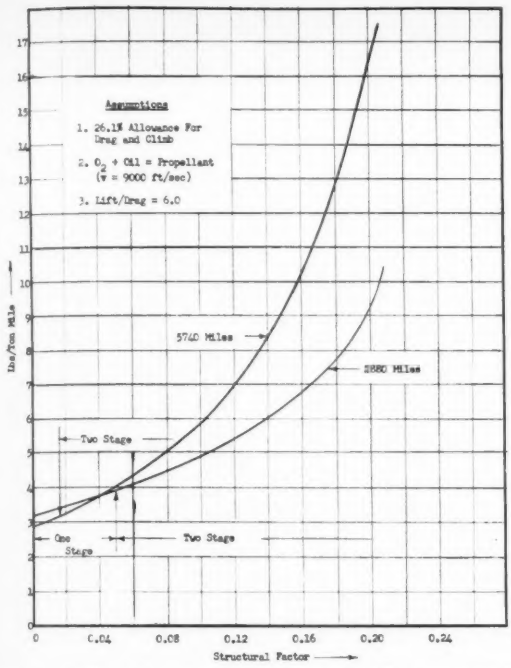



FIG. 4-3. Effect of structural weight on propellant consumption in rocket aircraft.

The rocket-powered airplane must climb from the surface of the earth to an altitude of about 30 miles during the acceleration process. Completely aside from the inescapable aerodynamic drag described above, this climb represents a lot of work. Define the optimum acceleration program as that which accomplishes the desired acceleration with the minimum expenditure of propellant. So far as the writer is aware, no one has been able to derive a workable, explicit, analytical expression for the optimum path. In practice, a series of "cut and try" paths are computed. Each path must be computed in a tedious step-by-step process. In addition, one must include the restriction that the aerodynamic forces on the airplane must be kept small so as not to endanger the structural integrity of the vehicle.

Finally, it will often be found that propellant consumption, as obtained by the successive approximation method described above, may be reduced still further by judicious programing of the thrust. The thrust at any portion of the flight may be limited by considerations of physiological welfare of the cargo. The interaction between the size of the rocket thrust chamber and its weight must also be considered.

Most of these nuances have been considered by Sänger and Bredt.[4] The acceleration allowance used in this study (26.1 per cent) is based on Fig. 65, page 102 of their report.

A little thought will convince one that the acceleration allowance is not the constant percentage of the terminal velocity assumed in this report. Instead, the necessary velocity increment may be divided into two parts: the necessary increase in gravitational potential entailed by the climb to altitude and the unavoidable aerodynamic drag incurred during the acceleration process.

Numerically, the increase in the gravitational potential of the airplane, when flying at 160,000 ft., corresponds to the kinetic energy of the airplane when flying at 3,200 ft./sec. This energy must be given to the airplane even if there is no aerodynamic drag, or, stated differently, even if the lift/drag ratio of the airplane is infinite.

Throughout the acceleration process an aerodynamic drag will act on the airplane. This drag loss constitutes the second component of the acceleration loss. As shown in reference 5, this loss may be materially reduced by optimizing the direction of the thrust vector during the acceleration process.

It is interesting to note that Sänger,[4] according to his Fig. 55, allows approximately 1,000 m./sec. for the acceleration losses. The effect on propellant consumption of changing the acceleration allowance is shown in Fig. 4-4.

(c) *Expected propellant performance:* Regardless of the propellants selected, the larger portion of the burning will take place above the atmosphere. Under these conditions, the pressure ratio across the rocket nozzle will be several hundred or more. Consequently, the effective exhaust velocities will be substantially greater than shown in Figs. 4-8 and 4-9 of "Rocket Propulsion Elements" by Sutton,[6] wherein a pressure ratio of only 20 to 1 was assumed. Sutton's Figs. 3-12 and 3-13 were used to help estimate the effective exhaust velocities used.

Three different propellant mixtures were considered:

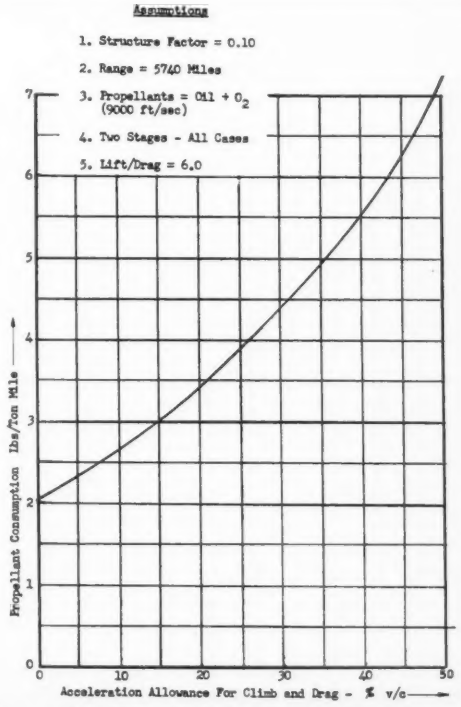

Assumptions
1. Structure Factor = 0.10
2. Range = 5740 Miles
3. Propellants = Oil + $O_2$ (9000 ft/sec)
4. Two Stages - All Cases
5. Lift/Drag = 6.0
Propellant Consumption lbs/Ton Mile
Acceleration Allowance For Climb and Drag - % v/c

FIG. 4-4. Effect of acceleration allowance assumptions on propellant consumption in rocket aircraft.

TABLE 4-3. PROPELLANT COSTS

| I. Assumptions | | | | | |
|---|---|---|---|---|---|
| CASE | A | B | C** | D | E |
| Propellants | $O_2$ + oil | $O_2$ + oil | $O_2$ + oil | $O_2$ + $H_2$ | $O_2$ + $H_2$ (9/1 mixture ratio) |
| Cost of Propellant Mixture (cent/lb) | 0.887 | 0.887 | 0.887 (2.0 for fuel used in lifting engines) | 2.0 | 1.25 |
| Acceleration Allowance (%) | 26.1 | 26.1 | 0.0 | 26.1 | 26.1 |
| Structural Factor | 0.10 | 0.20 | 0.10 | 0.15 | 0.10 |
| II. Propellant Costs (cent/ton mile) | | | | | |
| RANGE (miles) | | | | | |
| 420 | 5.37* | 8.05* | 4.14* | 8.20* | 6.35* |
| 825 | 5.03* | 9.8* | 3.30* | 7.10* | 6.25* |
| 2,880 | 4.47 | 8.18 | 2.64* | 6.40* | 6.14*) 5.14 ) |
| 5,740 | 5.07 | 14.75 | 2.36* | 6.04 | 5.66 |
| 10,880 | 8.45 | 3-stage | 2.10 | 6.62 | 7.10 |

*Single Stage; all others Two Stage unless otherwise indicated.
**Case C is an advanced design. Lifting engines are used to perform the initial portions of the acceleration, and an effective exhaust velocity of 10,000 ft/sec was assumed.

A 100% load factor was assumed in computing all the above costs. To get an 80% load factor, multiply by 1.12.

The first is liquid oxygen and oil. The oil may be JP-4, gasoline, diesel fuel, or any similar hydrocarbon. A mixture ratio (oxidizer to fuel) of 2.75 was assumed. The mean effective exhaust velocity of hot gas from the combustion chamber was assumed to be 9,000 ft./sec.

The second propellant combination considered is liquid hydrogen and liquid oxygen burned together with a mixture ratio, oxygen/hydrogen, of 4.0. An exit velocity of 12,330 ft./sec. was assumed.

Finally, liquid hydrogen and liquid oxygen having a mixture ratio, oxygen/hydrogen, of 9.0 was considered. An exit velocity of 10,460 ft./sec. was assumed.

(d) *Resultant v/c requirement:* The required ratio of (ideal, theoretical rocket velocity at end of burning)/(effective gas exit velocity) is denoted by $v/c$. The curves of reference 5 were used to determine this ratio. A typical result of such a determination is shown in Fig. 4-1.

(2) *Propellant Consumption—*

(a) *Effect of structural weight:* The ratio of the weight of a single stage when completely empty (no propellants, no pay load) to the gross weight of the stage when completely full, is defined as the *structural factor* (denoted by $\delta$). For reasons described in a previous paper,[7] the writer is inclined to agree with Sänger and Bredt[4] that a value of 0.10 is a reasonable assumption for the structural factor. However, the effects of assuming a more conservative value for the structural factor are shown in Fig. 4-3. It is important to notice that the propellant performance assumed is close to the theoretical attainable limit. Consequently, no great improvement may be expected.

No such definite theoretical limit exists for the structural factor.[13] Such limits as have been prescribed by theory are far beyond those herein discussed. Comparatively, therefore, the field of weight reduction is wide open; designs may be expected in which important reductions in weight have been achieved.

(b) *Results:* The total fuel consumption of a stepped rocket of $n$ steps is given by van der Wal.[5] Numerical results for some typical examples are given in Fig. 4-2.

(3) *Unit Cost of Propellants—*

(a) *Assumptions:* Two propellant combinations were considered: (1) petroleum oil and liquid oxygen (mixture ratio—oxygen/oil = 2.75) and (2) liquid hydrogen and liquid oxygen (mixture ratio—oxygen/hydrogen = 4.0, and mixture ratio—oxygen/hydrogen = 9.0). Except for the 9.0 case, the mixture ratio selected was chosen so as to minimize the unit cost of the propellant mixture without unduly compromising its performance.

Liquid Oxygen: In all cases, oxygen is by far the cheaper propellant component. Liquid oxygen of commercial purity is currently being sold at prices ranging from $20- to $30/ton. There are studies, however, which indicate that, if there were really a large-scale demand for oxygen, the price would be reduced to $5.00 or $10/ton at the production site.

Hydrocarbon Oil: The hydrocarbon oil is selected as the cheapest available distillate fuel. The cost of this fuel is assumed to be 12 cents/gal. or 2 cents/lb. The Air Force has obtained JP-4, a fuel of higher quality, at prices less than 2 cents/lb. It is, therefore, felt that 2 cents/lb. for the hydrocarbon oil is a conservative figure. See also Appendix 1, "Fuel Costs."

Other Possible Fuels: Ammonia and hydrazine are both attractive from the standpoint of their performance in rockets. Unfortunately, there is little reason for believing that they will ever be cheaper than oil on a basis of cost per unit weight. In addition, oil, burning to carbon dioxide and water, requires more oxygen per pound of fuel than either ammonia or hydrazine. Since the oxygen is the cheaper component, the cost of the propellant mixture is reduced whenever the oxygen/fuel ratio is increased. Therefore, even if ammonia and hydrazine cost no more than oil, the cost of the propellant mixture, ammonia-oxygen or hydrazine-oxygen, would still be more than the cost of the gasoline-oxygen mixture.

Hydrogen-Fluorine: The hydrogen-fluorine system has a very high specific impulse. However, the added cost incurred by using this or any other high-performance fuel can easily be shown to outweigh greatly the advantage of increased exit velocity.

Hydrogen: Commercial hydrogen is currently produced by three processes: electrolysis of water, reaction of steam on hot carbon, and dehydrogenation of petroleum in petro-chemical plants. In all these methods, the unit cost of the hydrogen produced is a sensitive function of both the cost of the ingredients consumed and of the value of possible by-products. In order to avoid a complex economic study, the writer estimated that the cost of liquid hydrogen is 8 cents/lb. A production cost of 8 cents/lb. may be approached in a plant electrolyzing water in which the cost of electric power is no more than 4 cents/kilowatt hour. A more recent source of cheap hydrogen is a by-product from petro-chemical manufacturing. The value of 8 cents/lb. is believed to be somewhat optimistic and should be used as a lower bound when comparing the relative virtues of hydrogen and oil as rocket fuels.

(*Continued on page 71*)

*The use of a spring-loaded cam to create "artificial feel" for an airplane control system requires the design of a cam contour that will produce a desired cam moment vs. cam rotation function. Using an energy relation, it is possible to calculate directly points for the required contour without solving a differential equation.*

# Calculation of Feel Cam Contour

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Republic Aviation Corporation

## Introduction

In fully powered aircraft control systems, the pilot operates the control surface by means of a servo, with the result that he does not feel aerodynamic forces at the control stick as with an unpowered system. Thus it is necessary to supply artificial stick forces or "feel" to help him control the airplane. A basic part of such "artificial feel" is the variation of stick force as a function of stick position, and a convenient means of doing this is with an appropriately shaped spring-loaded cam. Such a feel cam can generate a wide range of force functions, as well as allow design changes by merely introducing a new cam. We proceed to develop the analysis for calculating such a cam contour so as to obtain any desired variation of cam moment with cam rotation.

## System Geometry

Consider the two-dimensional geometry of the cam system as shown in Fig. 1. The basic system is given by taking the fixed cam pivot point $O$ as origin with the positive $x$ axis through $Q$ and specifying the following information:

(1) Coordinates of roller pivot point $Q(A, O)$
(2) Coordinates of spring pivot point $T(a, b)$
(3) Spring arm $C$
(4) Roller arm $E$
(5) Roller radius $r$
(6) Angle the roller arm makes with the spring arm, $\alpha = \angle SQB$ (positive when counterclockwise).

Specification of the configuration for the neutral position can be done by choosing the corresponding length of the spring $L_0$. We also need to know the unstretched length of the spring, $l$, and its spring rate constant $K$.

With the cam in its neutral position, we set up an $(x', y')$ coordinate system fixed in the cam and aligned with the $(x, y)$ system that is fixed in structure. Cam rotation angle $\lambda$ is zero for neutral and is defined as the angle to which the $(x', y')$ system has been rotated counterclockwise relative to the $(x, y)$ system. The desired external moment required to rotate the cam through an angle $\lambda$ and defined positive when in the counterclockwise sense is given as in Fig. 2 by $M(\lambda)$ as a function of $\lambda$.

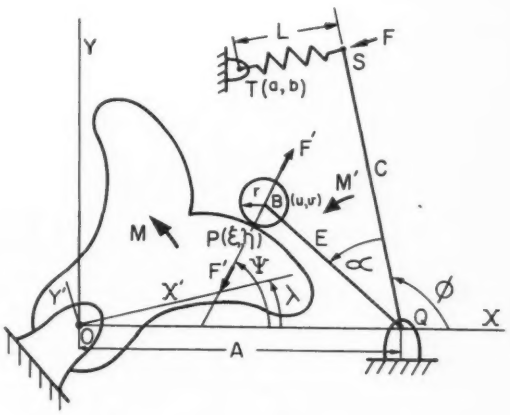


Fig. 1. Geometry of feel cam system.

## Energy Relationship

Neglecting friction in the system, the work $W$ done by this external moment in rotating the cam from neutral to a position $\lambda$ is equal to the corresponding increase in the potential energy of the spring. First we obtain $W$ by the relation

$$W = \int_0^{\lambda} M(\lambda)d\lambda \tag{1}$$

Then to calculate $F$, the force exerted by the spring,

$$W = (1/2)K(L - l)^2 - (1/2)K(L_0 - l)^2$$
$$= (1/2K)(F^2 - F_0^2)$$

or

$$F = \pm\sqrt{2KW + F_0^2} \tag{2}$$

where $L$ is the length of the spring, and $F_0 = K(L_0 - l)$. Now $L$ can be obtained from $F$ by

* Chief Dynamic Analysis Engineer.

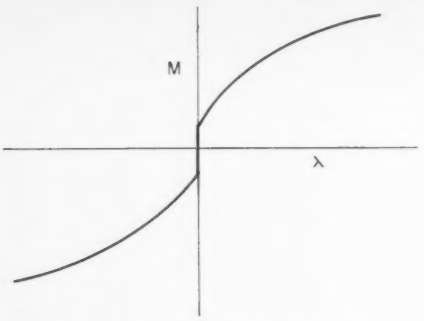


FIG. 2. Cam moment vs. cam angle.

$$L = (F/K) + l \tag{3}$$

We take the positive square root in Eq. (2) for the case with the spring in tension, and we take the negative for compression.

### ROLLER SYSTEM

Once $L$ is known, we can calculate the complete roller system geometry. The point $S$ is determined as the intersection of two circles: one with center at $T$ and radius $L$, and the other with center at $Q$ and radius $C$. There will be two such intersections, and a design choice must be made to select the desired one.

To proceed, we first calculate $\phi$, the polar angle for $\boldsymbol{R}_{QS}$.

$$\begin{aligned} \boldsymbol{R}_{QT} &= (a - A)\boldsymbol{i} + b\boldsymbol{j} \\ \boldsymbol{R}_{QS} &= C(\cos\phi\boldsymbol{i} + \sin\phi\boldsymbol{j}) \\ L^2 &= (\boldsymbol{R}_{TS})^2 \\ &= (\boldsymbol{R}_{QS} - \boldsymbol{R}_{QT})^2 \\ &= (\boldsymbol{R}_{QS})^2 + (\boldsymbol{R}_{QT})^2 - 2\boldsymbol{R}_{QS}\cdot\boldsymbol{R}_{QT} \end{aligned}$$

or $$(a - A)\cos\phi + b\sin\phi = D$$

where

$$D = (1/2C)[C^2 + (a - A)^2 + b^2 - L^2] \tag{4}$$

Then

$$\sin\phi = \frac{Db \pm (a - A)\sqrt{(a - A)^2 + b^2 - D^2}}{(a - A)^2 + b^2} \tag{5}$$

$$\cos\phi = \frac{D(a - A) \mp b\sqrt{(a - A)^2 + b^2 - D^2}}{(a - A)^2 + b^2} \tag{6}$$

and $$u = E\cos(\phi + \alpha) + A \tag{7}$$

$$v = E\sin(\phi + \alpha) \tag{8}$$

The moment about $Q$ (defined positive in the counterclockwise sense) produced by the spring on the roller system we denote by $M'$, which is given by

$$\left.\begin{aligned} M' &= \boldsymbol{k}\cdot\boldsymbol{R}_{QS} \times (F\boldsymbol{R}_{ST}/L) \\ &= (F/L)\boldsymbol{R}_{QS}\cdot(\boldsymbol{R}_{QT} \times \boldsymbol{k}) \\ &= (FC/L)[b\cos\phi - (a - A)\sin\phi] \\ &= \mp(FC/L)\sqrt{(a - A)^2 + b^2 - D^2} \end{aligned}\right\} \tag{9}$$

Thus in choosing between the two solutions for the roller system geometry, we see that, if a tension force in the spring (i.e., $F > 0$) is to produce a counterclockwise moment at $Q$, we take the + sign in Eqs. (6) and (9) and the − sign in Eq. (5). The signs are reversed to obtain the other solution if tension in the spring is to produce a clockwise moment at $Q$.

### POINT OF CONTACT

Disregarding friction, the cam normal at the point of contact $P$ passes through the roller center $B$. Thus for equilibrium, the reaction force between the cam and the roller, $F'$, can be considered as applied at the roller center to produce counterclockwise moment $-M'$ about $Q$ and $-M$ about $O$.

Let $\boldsymbol{R}_{PB} = r(\cos\Psi\boldsymbol{i} + \sin\Psi\boldsymbol{j})$, where $\Psi$ denotes the polar angle for $\boldsymbol{R}_{PB}$.

Equating to $-M'$ the counterclockwise moment on the roller system produced around $Q$ by $F'$, we obtain

$$\begin{aligned} -M' &= \boldsymbol{k}\cdot\boldsymbol{R}_{QB} \times (F'\boldsymbol{R}_{PB}/r) \\ &= (F'/r)\boldsymbol{R}_{PB}\cdot(\boldsymbol{k} \times \boldsymbol{R}_{QB}) \\ &= F'[\cos\Psi\boldsymbol{i} + \sin\Psi\boldsymbol{j}]\cdot[-v\boldsymbol{i} + (u - A)\boldsymbol{j}] \\ &= F'\cos\Psi[-v + (u - A)\tan\Psi] \end{aligned}$$

Similarly, with regard to the moment on the cam produced around $O$ by $F'$,

$$\begin{aligned} -M &= \boldsymbol{k}\cdot\boldsymbol{R}_{OB} \times (F'\boldsymbol{R}_{BP}/r) \\ &= (-F'/r)\boldsymbol{R}_{PB}\cdot(\boldsymbol{k} \times \boldsymbol{R}_{OB}) \\ &= -F'(\cos\Psi\boldsymbol{i} + \sin\Psi\boldsymbol{j})\cdot(-v\boldsymbol{i} + u\boldsymbol{j}) \\ &= F'\cos\Psi(v - u\tan\Psi) \end{aligned}$$

Eliminating $F'$ from these equations, we solve for $\tan\Psi$

$$\tan\Psi = [v(M + M')]/[u(M + M') - AM] \tag{10}$$

To determine the quadrant for $\Psi$, we obtain the algebraic sign for $\cos\Psi$. Assuming that the roller is always pressed against the cam, then the reaction force $F'$ as used before will be positive. Taking the absolute value for both sides of our previous result,

$$|M| = F'|\cos\Psi|\,|v - u\tan\Psi|$$

Then $$\frac{\cos\Psi}{|\cos\Psi|} = \frac{M}{|M|}\,\frac{u\tan\Psi - v}{|u\tan\Psi - v|} \tag{11}$$

The coordinates of $P(\xi, \eta)$ in the $(x, y)$ system are given by

$$\xi = u - r\cos\Psi \tag{12}$$

$$\eta = v - r\sin\Psi \tag{13}$$

Then the coordinates of $P(\xi', \eta')$ in the $(x', y')$ system are

$$\xi' = \xi\cos\lambda + \eta\sin\lambda \tag{14}$$

$$\eta' = \eta\cos\lambda - \xi\sin\lambda \tag{15}$$

Eqs. (1) through (15) thus allow us to calculate points on the required cam contour, with $\lambda$ acting as a parameter. A breakout discontinuity as shown in Fig. 2 will be taken into account by the formulas, and two points of contact are determined from the two values of $M$ corresponding to the breakout point.

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# Nuclear Aircraft Shielding

*Types of radiation from nuclear reactors and their effects are discussed in relation to shielding materials and configurations for aircraft applications.*

THERE HAS BEEN much discussion of the possibility of installing nuclear power plants in aircraft. This would, of course, have the advantage of giving an unlimited range to the aircraft at the cost of introducing radiation problems with their consequent design limitations. It is implicit in the notion of a nuclear power plant for aircraft that the reactor shield weight must be reduced to a minimum. Because of the complexity of the subject, it is not the intention of this paper to present any spectacular new discoveries or any new elegant and sophisticated mathematical techniques. Rather, the aim is to present to the aeronautical engineer some of the basic concepts associated with the design of shielding to limit radiation to tolerable levels for aircraft applications.

The principal types of radiation associated with nuclear reactors are betas, gammas, and neutrons. Beta particles can be stopped by a few thousandths of an inch of solid material. High-energy (or hard) gammas, on the other hand, are very penetrating and may require many inches of lead. High-energy (or fast) neutrons are much more massive particles which, strangely enough, can be slowed down and stopped most effectively by the use of light materials. If we consider a typical fission type of reactor, we find that approximately $2^1/_2$ fast neutrons and about a dozen hard gammas are released per fission. Since there are approximately $3 \times 10^{10}$ fissions/watt, it follows that there are approximately $7 \times 10^{10}$ neutrons/sec. emitted per watt and approximately $3 \times 10^{11}$ gammas/sec. emitted per watt. Roughly two thirds of these neutrons and gammas are absorbed in the reactor core; the balance escape into the shield.

By themselves, these numbers seem meaningless. It appears in order to relate the commonly used measures of radiation intensity, the curie and the roentgen, to the number of gammas striking a given area. A curie has been defined as being a source of radiation in which there are approximately $3 \times 10^{10}$ disintegrations/sec. A roentgen is a measure of radiation dose. While it depends on the gamma energy (see Table 1), a roentgen can be considered as a radiation dose roughly equivalent to $2 \times 10^9$ gammas/cm.$^2$. The damaging effects of neutrons and gammas are not the same, but a rough equivalence in damage to living tissue is given by $2.5 \times 10^7$ fast neutrons/cm.$^2$, and such a dose is defined as a rem, or a "roentgen equivalent man." (As indicated in Table 1, slow neutrons are much less damaging.) The term man is used because, as will be indicated later, various types of living tissue differ in their sensitivity to neutrons and gammas. Organic compounds in general are one tenth as sensitive to neutrons relative to gammas as is living tissue. For this reason a "roentgen equivalent physical" dose, or rep, is also used.

We are often interested in dose rates rather than integrated doses, so that radiation dose rates are expressed in roentgens or rem per hour—e.g., 0.01 r/hour or 0.01 rem/hour. Since the dose rates are usually small, milliroentgens or millirem are commonly used—e.g., 10 mr/hour or 10 mrem/hour. Similarly, the terms neutron flux and gamma flux are widely used to state the number of neutrons or gammas passing through a 1 sq.cm. area per sec.

These concepts and units can best be related by considering a particular case. Suppose that we have a very small reactor which is operating at a power of 1 watt. It will then be emitting approximately $1.0 \times 10^{10}$ neutrons/sec. and $1.2 \times 10^{11}$ gammas/sec. If we consider a hollow spherical shell 1 m. in radius with this little 1-watt reactor at its center, the radiation incident on each sq.cm. of that spherical surface will be the total radiation emitted from the reactor divided by the area of the sphere which is approximately $10^5$ cm.$^2$. Thus, the gamma radiation dose rate at the surface of the sphere with no shielding between the 1-watt reactor at the center and the spherical surface would be

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$$\text{Gamma dose rate} = \frac{(\text{gammas/sec.-watt})(\text{sec./hour})}{(\text{gammas/cm.}^2\text{-roentgen})(\text{cm.}^2)} = \frac{12 \times 10^{10} \times 3{,}600}{2 \times 10^9 \times 10^5} = 2 \text{ r/hour-watt}$$

Similarly,

$$\text{Neutron dose rate} = \frac{10^{10} \times 3{,}600}{2.5 \times 10^7 \times 10^5} = 14 \text{ rem/hour-watt}$$

For many years, the strength of a radiation source has been expressed in terms of curies of radioactivity. A curie has been defined as a radiation source in which there are approximately $3 \times 10^{10}$ disintegrations/sec. While different radioactive materials differ in the intensity of the radiation that they emit, it is evident that a 1-curie source of hard gamma rays is roughly equivalent to a 1/2-watt reactor in terms of the gamma shielding problem that it imposes. The above definitions and concepts are presented in tabular form in Table 1. It should be remembered that this is an oversimplified set of approximations and that actually the energy of the particles emitted from a fission source is not uniform but varies. Both the gamma rays and the neutrons emitted in the fission process vary in energy over a fairly wide range, most of them being somewhere between 1/2 mev and 10 mev with the greater part having energies around 1 mev. Fig. 1 shows a curve of the energy distribution of the neutrons from a typical fission source.

All of the above terms are meaningless unless they are related to the radiation damage that will be done by neutrons and gammas. Living tissue is more sensitive to radiation damage than any other material. Of the various forms of life, the higher forms seem to be more sensitive and the lower forms less sensitive to radiation. That is, mammals are much more sensitive to radiation than bacteria, and the more complex molecules in mammals are more sensitive to radiation than the less complex molecules—e.g., the chromosomes and genes in mammals are especially sensitive. A question may arise as to sources of data on radiation damage. There is not a thoroughly complete picture of the deleterious effects of radiation on man for obvious reasons. We do have much data obtained from the routine use of radiological exposures in medical work. X-ray treatments for cancer and other malignancies have given us a considerable background of information on both the irradiated patients and the radiologists who have handled the equipment for the irradiation. Because of the variation in the sensitivity of individuals to radiation, a useful parameter is the radiation dose at which 50 per cent of the subjects die as a result of radiation. This is called the LD-50 dose—i.e., the lethal dose for 50 per cent of the subjects exposed. This LD-50 dose runs about 400 r, if the dose is given in a single, relatively short period of time. If the dose is spread out over a period of weeks or years, then a total dose, perhaps twice or three times as great, can be absorbed. Unfortunately, many deleterious effects of radiation appear after radiation dosages of much less than the LD-50 dose. These effects include superficial burns, eye cataracts, leukemia, sterility, genetic effects, and shortening of the normal life span.

It has become clear that the total lifetime radiation dose for personnel ought not exceed 25 r for planned operations. The International Commission of Radiological Protection has set up standard laboratory radiation dose tolerances that are widely used. These permit an exposure of 350 mr/week for personnel working in areas involving radiation hazards. It is, of course, expected that personnel will not receive a 350-mr dose each week of their working careers but, rather, that only in a relatively small percentage of the working weeks of their lifetimes will they be exposed to so large a dose as the tolerance dose. This dose may be accumulated in a very short period of time—say 5 min.—or it may be accumulated over the course of the entire week's work. Further, in the event of serious emergencies, it is considered that a dose of 25 r is a reasonable

TABLE 1
Definitions of Basic Terms

| | |
|---|---|
| Curie | Unit of radioactivity equal to 37 billion ($3.7 \times 10^{10}$) disintegrations per sec. and is represented by the symbol c. The millicurie, mc., is one thousandth of a curie, and the microcurie, $\mu$c, is one thousandth of a millicurie, or 37,000 disintegrations per sec. |
| Mev | Abbreviation for million electron volts. It is a unit of energy equal to $1.6 \times 10^{-6}$ ergs. The energies of most of the normally encountered nuclear radiations lie between 0.01 and 3.0 mev. |
| Roentgen | (Milliroentgen) is a measure of $x$- or gamma radiation in a region. One roentgen produces one electrostatic unit of charge as a result of ionization in 1 cm.$^3$ of dry air at standard temperature and pressure. The table below shows the number of gammas per roentgen for each of several gamma energies. |
| Rep | (Millirep), the roentgen equivalent physical dose, is a measure of both gamma and neutron radiation damage to organic material, one rep being the amount of radiation required to deposit 93 ergs per gm. of animal tissue. For practical purposes, one roentgen can be considered as equal to one rep. |
| Rem | The roentgen equivalent dose for man is a measure of both gamma and neutron radiation dose. While it depends on the type of tissue involved, the neutron energy, etc., the table below shows the amount of neutron or gamma radiation for a unit of dose. |

Amount of Radiation per Unit of Radiation Dose

| | Gammas/cm.$^2$ | | | | Neutrons/cm.$^2$ | | | |
|---|---|---|---|---|---|---|---|---|
| Energy, mev | 5 | 1 | 0.5 | 0.1 | 5 | 1 | 0.5 | 0.1 |
| Roentgen | $5.4 \times 10^9$ | $2 \times 10^9$ | $3.6 \times 10^9$ | $8 \times 10^9$ | | | | |
| Rep | $5.4 \times 10^9$ | $2 \times 10^9$ | $3.6 \times 10^9$ | $8 \times 10^9$ | $2.8 \times 10^8$ | $2.8 \times 10^8$ | $4 \times 10^8$ | $1.05 \times 10^9$ |
| Rem | $5.4 \times 10^9$ | $2 \times 10^9$ | $3.6 \times 10^9$ | $8 \times 10^9$ | $1.2 \times 10^7$ | $2.8 \times 10^7$ | $4 \times 10^7$ | $1.05 \times 10^8$ |

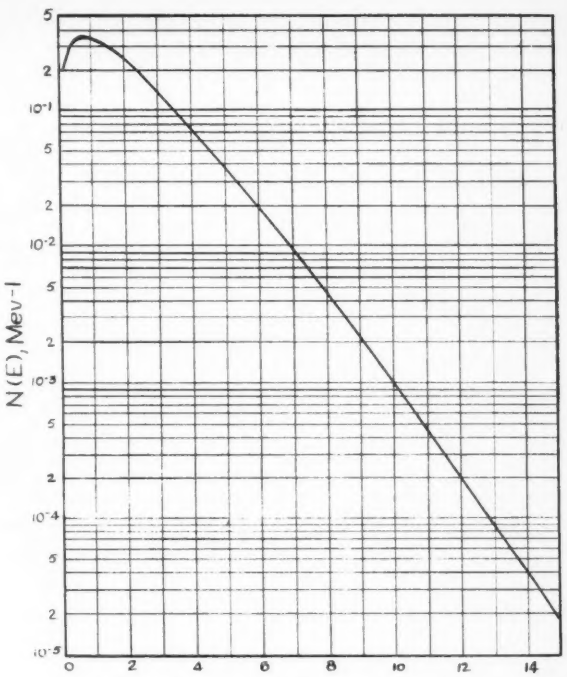
one to accept. Of course, it would be expected that the same personnel would not be exposed to these emergency doses more than once.

It should be pointed out that, if radioactive material is ingested either through the lungs or through the digestive system, it may be deposited in certain key organs or in the bone marrow. If this occurs, the radioactive material will continue to decay for the balance of the life of the subject and will expose him to quite substantial radiation dosages. The famous case of radium poisoning among workers in a Newark watch factory in the 1920's gives an instance of this type of radiation poisoning. If it occurs, little or nothing can be done to alleviate the condition of the patients. For this reason, the concentration of radioactive dust in the air must be kept to a very low level, and, similarly, great precautions must be taken to ensure that personnel and clothing exposed to radioactive material be thoroughly cleaned so that there will be no contamination of the food or water of the personnel which would result in radioactive poisoning of their bodies.

A very considerable amount of research work has been conducted in recent years on the radiation damage to organic materials. In general, the results of this work can be summarized by saying that the elastomers are the most sensitive of the common organic materials while plastics are somewhat less sensitive. Liquids are still less sensitive, and tarry materials are the least sensitive. In general the benzene ring compounds are the least affected by radiation. Also, the less complex molecules are less sensitive to radiation. In general, it can be said that the most sensitive organic compounds will show appreciable radiation damage after exposure to $10^7$ r while the least sensitive materials, such as tars, will withstand as much as 100 to 1,000 times as much irradiation. The damage takes several forms.

Inorganic compounds and elements are in general quite insensitive to irradiation. While certain properties of some crystals and certain glasses are conspicuously sensitive to irradiation, for most purposes the effects of gamma or fast neutron irradiation are not serious. Gamma irradiation ordinarily has little effect. Fast neutron irradiation causes dislocations of atoms in the crystal lattice which tend to harden (and embrittle) the material and increase its electrical resistivity. If the irradiation is carried out at temperatures sufficiently high to permit annealing, these effects are inconsequential. The same can be said of ceramics although there are certain items that are quite sensitive to irradiation. Many glasses, for example, are very sensitive to irradiation and become opaque.

A very important effect of irradiation by thermal neutrons is that many neutrons will be captured by atoms in the irradiated material and artificially radioactive material will be produced. While activation by gamma rays can also occur, the effect is trivial relative to that for neutrons. The consequences of neutron activation depend upon three important properties—the neutron-capture cross section of the particular material, the half life of the new isotopes produced by



Watt's Spectrum Of Fission Neutrons

Fig. 1.

the neutron captures, and the character and energy of the radiation emitted in the decay process. For example, if aluminum is exposed to slow neutrons, it has a low-capture cross section so that the number of captures tends to be small. More important, even where neutrons are captured in aluminum, the new radioactive atoms form decay with a short half life so that, in a relatively short time, the intensity of the radiation emitted from the aluminum is small. On the other hand, cobalt has a large-capture cross section so that it is very inclined to capture neutrons, and it decays with a very long half life. As a result, materials containing cobalt become intensely radioactive in the course of exposure to a slow neutron flux, and their activity decays at a rate such that it drops in intensity only by a factor of two in $5^1/_2$ years.

In designing the shielding for any particular application, there are a number of points that must be kept in mind. The fast neutrons emitted from a reactor must be slowed down and, if possible, captured in a material which will not be rendered highly radioactive by the neutron captures. Further, if possible, the captures ought to be effected in a material which will not emit a hard-capture gamma. In general, most materials emit one or more gamma rays of from 3 to 10 mev at the instant a neutron is captured. Of all the elements, only two isotopes, $B^{10}$ and $Li^6$, do not emit these hard-capture gamma rays. It is clear that there is little point in slowing down neutrons far out in a shield and then capturing them in a material which will be responsible for the emission of a hard gamma ray that will be only less destructive than the fast neutron

TABLE 2
Relaxation Lengths for Fast Neutrons and Gamma Rays

| Material | Density (g/cm.³) | Relaxation Length (cm.) Fast Neutrons | Relaxation Length (cm.) Gamma Rays |
|---|---|---|---|
| Water | 1.0 | ~10 | 30 |
| Graphite | 1.62 | ~ 9 | 19 |
| Beryllium | 1.85 | ~ 9 | 18 |
| Beryllium oxide | 2.3 | ~ 9 | 14 |
| Concrete | 2.3 | 11 | 15 |
| Aluminum | 2.7 | ~10 | 13 |
| Baryten concrete | 3.5 | 8.0 | 10 |
| Iron concrete | 4.3 | 6.3 | 8 |
| Iron | 7.8 | ~ 6 | 3.7 |
| Lead | 11.3 | ~ 9 | 2.5 |

would have been and more difficult to shield. In general, neutrons can be slowed down most effectively by allowing them to strike light atoms such as hydrogen, carbon, or beryllium. In the course of each impact, the neutron imparts some of its energy to the light atom involved so that, after a number of collisions, it will be slowed down to thermal energies—i.e., it will move about in the crystal lattice with the velocity of a hydrogen atom in a gas at the prevailing temperature. Water is a particularly effective medium for slowing down neutrons because of its high hydrogen content, and it is a very convenient medium with which to work. Because of this, a fair number of reactors have been designed and built to operate in a large pool of water so that the water serves not only as a means of cooling the reactor and carrying off the heat but also as a means of shielding the radiation emanating from the reactor. It is very instructive to examine the curves of Fig. 2 which give both the neutron and gamma radiation dose levels in the water shield of such a reactor at various distances from the surface of the reactor core. Note how rapidly the neutrons are attenuated by the water. Note, too, that the gamma flux is attenuated much less rapidly. Changes in slope of the attenuation curves for both neutrons and gammas occur because the lower energy photons and neutrons are removed much more rapidly than the high-energy radiation. As a result, the radiation spectrum changes with distance from the core and becomes progressively harder as one moves radially outward in the shield. This tendency is common in shield materials.

The gamma radiation is attenuated by several processes, all of which are different in mechanism from that of the neutron attenuation. Basically, the gamma flux is attenuated by interaction between the gammas and the electrons in the medium through which the radiation is passing. This means that the rate of gamma attenuation is essentially directly proportional to the density of the material employed as a shield. Thus, a slab of a dense material such as lead is more effective on a volumetric basis than a slab of a light material such as water. However, the total mass of material required to effect the attenuation of a given beam of radiation is approximately independent of the type of material used, at least within a factor of two. In general, the more dense materials are a bit more effective on a weight basis. In addition, they are likely to be more effective in that the source is usually a relatively small cylinder or sphere and the quantity or volume of shielding material required varies as the cube of the shield radius, so that the area of each incremental layer increases fairly rapidly with the shield thickness. In this way, a very marked weight advantage can be shown for a dense material such as lead as compared to a light material such as water in shielding sources of gamma radiation.

A convenient means of expressing the effectiveness of a material for shielding purposes is to make use of its so-called "attenuation length." This is the thickness of the material required to reduce the radiation dose by a factor of $e$—that is, 2.73. Thus, roughly 1 in. of lead or 10 in. of water will effect a reduction in gamma dose by a factor of $e$ if slabs of these thicknesses are interposed between the radiation source and the detector. Table 2 presents data for a number of common materials that might be used for radiation shielding. Note that attenuation lengths are given for both neutrons and gammas and that the neutron and gamma energies given in the table are simply considered representative. Considerably more detailed information is available.[1]

Each radiation source requiring a shield presents a different set of problems so that, in each instance, the shield must be tailored to the case in hand. If an effort is made to minimize shield weight, factors such as configuration of the equipment required in the vicinity of the source of radiation, penetrations through the shield represented by instrument lines or ducts, and problems of thermal insulation, cooling, etc., must all be accommodated. Because of this, it is very difficult to select any configuration that could be considered as representative. Probably the most instructive thing to do would be to consider the Geneva reactor and determine the shield weight required to achieve a given radiation dose level with a given reactor power output. Assume, for example, that the radiation dose level at the surface of the shield is to be kept to 1 r/hour and that the reactor power output is to be 1,000 kw. of heat. If this reactor were coupled to a thermodynamic cycle having an overall cycle efficiency of 25 per cent, the nuclear power plant would deliver approximately 300 useful mechanical horsepower. Fig. 2 can be used to obtain a solution for the shield thickness very simply. Since the 1,000-kw. reactor would operate at a power level of $10^6$ watts, the design radiation dose at the shield surface would be $10^{-6}$ rem/hour-watt. From Fig. 2 it can be seen that this dose level would be obtained with a water shield thickness of 144 cm., or 56.6 in. It can also be seen from Fig. 2 that the gamma dose for this shield thickness would be too high by a factor of $10^4$. Since $e^{9.2} = 10^4$, the thickness of lead required would be 9.2 attenuation lengths, or about 9.2 in. The shield weight can be estimated from these values. The reactor core can be considered as a 20-in.-diameter sphere surrounded by a shield 56.5 in. thick. (Note that Table 2 shows that, for fast neu-

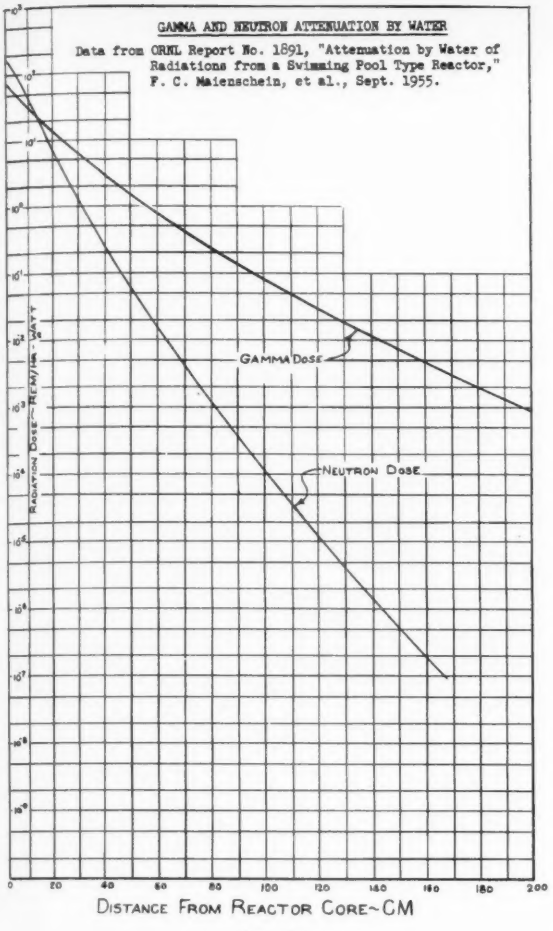

GAMMA AND NEUTRON ATTENUATION BY WATER
Data from ORNL Report No. 1891, "Attenuation by Water of Radiations from a Swimming Pool Type Reactor," F. C. Maienschein, et al., Sept. 1955.
GAMMA DOSE
NEUTRON DOSE
RADIATION DOSE—REM/HR - WATT
0 20 40 60 80 100 120 140 160 180 200
DISTANCE FROM REACTOR CORE~CM

FIG. 2.

trons, lead has essentially the same attenuation length as water.) The weight of the water would be 40,000 lbs. The weight of the lead layer will depend on its location, which must be far enough away from the core surface so that the neutron flux will be low enough to inhibit the production of capture gammas in the lead. A crude estimate of the proper location would be midway between the core surface and the shield surface. This gives a lead shield weight of 55,000 lbs. and a total shield weight of 95,000 lbs.

The use of a nuclear reactor in any type of aircraft will present many ground handling and maintenance problems. One of these will be that of afterheat and decay gamma radiation from the reactor after shutdown. It is possible to stop the fission reaction in a very short interval of time, but it is not possible in any way to affect the rate of decay of the fission products left after extended operation at high power. The amount of this afterheat is best presented in terms of a percentage of full-power output. Of course, the greater the length of time at which a reactor is operated at full power the greater the amount of fission products that will have accumulated.* The amount of this afterheat is essentially independent of the type of reactor employed, and provision for removing it must be made in the installation.

In addition to the heat evolved from the fission product decay, there is also a very strong source of gamma radiation present in the fission products. The magnitude of this radiation source varies from roughly one third of the gamma radiation at full power to values much less after extended periods of cooling, the decay rate being essentially the same as that of the afterheat.*

### REFERENCES

[1] *Reactor Shielding Design Manual*, Naval Reactors Branch, U.S. AEC. (Available from Office of Technical Services, Dept. of Commerce, Washington 25, D.C.)

[2] *The Reactor Handbook*, U.S. AEC, Supt. of Documents, Washington 25, D.C.

* A figure, presenting the afterheat as a function of time after shutdown for a series of times of operation at full power, was included in the preprint of this paper (No. 644).—ED.

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# Satellites

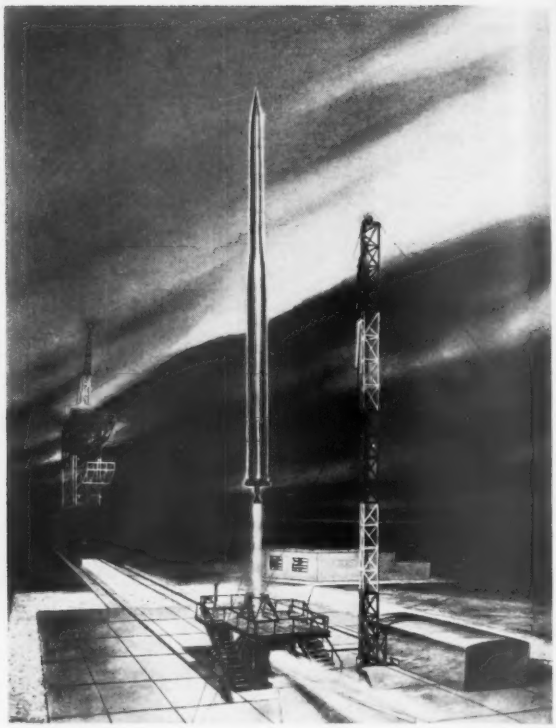

FIG. 1. Vanguard launch.

*In this, the dawn of an era which may become the age of space, man is experimenting with the magic his brain has wrought. Soon, he can expect to sprinkle the solar system with earth-made ornaments, but this author sees "something worth while" as another matter. Man, it seems, must continue to fight his way into the heavens.*

## INTRODUCTION

THE ANNOUNCEMENT last year that the United States was to establish an earth satellite in connection with the International Geophysical Year was a confirmation of the fact that the state of rocket development has now advanced to the stage where the prospect of space flight passes from the realm of speculation into the realm of engineering. Let us consider some of the engineering aspects of the Vanguard project.

The problem is to place a small satellite weighing approximately 20 lbs. into an orbit around the earth.[1] To achieve this, we must impart to the satellite a velocity in the order of 25,000 ft. per sec. This is the velocity at which the gravitational pull of the earth is balanced by the centrifugal force on the satellite. To attain this velocity, we intend to use a three-stage rocket with a total take-off weight of about 22,000 lbs. As announced, the overall dimensions of the launching vehicle are 72 ft. long and 45 in. wide. This rocket will be powered by a 27,000-lb. thrust engine and launched vertically from the Air Force Missile Test Center at Cape Canaveral in Florida. An artist's conception of the launching is shown in Fig. 1.

The 27,000-lb. thrust engine in the first stage of the rocket will burn liquid oxygen and kerosene for a period of more than 2 min. At the end of this period, the vehicle will be moving about 4,000 ft. per sec. at an angle of 45 deg. to the horizontal. When the first stage drops off, the smaller second-stage engine takes over the job of pushing the remainder of the rocket along a curving trajectory up to a velocity of about 14,000 ft. per sec., which is reached at 130 miles altitude. The second stage of the rocket, which has exhausted its supply of propellants (nitric acid and hydrazine), will now coast up to the satellite injection altitude of 300 miles. The final boost of the satellite package into the orbit will be provided by the third-stage solid propellant rocket which separates from the second stage at this point. The second stage subsequently impacts several thousand miles down range. At the end of third-stage burning, the satellite proper is gently separated from the empty third-stage propellant bottle, and they both sail serenely on; two satellites for the price of one.

Presented at the Eastern Regional Meeting, Institute of Navigation, Baltimore, April 26, 1956.

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The opinions expressed in this paper are those of the author and not necessarily those of The Glenn L. Martin Company.

### Auxiliary Jets to Establish Roll Stability

The control of the rocket's flight is achieved through the use of gimbaled engines which are tilted in pitch and yaw by hydraulic actuators. The control system or autopilot derives its information from an inertial reference system carried in the second stage of the rocket. All stages of the rocket are finless so that the engines also must provide for stabilization of the vehicle, as well as flight path corrections. Roll stability is accomplished by auxiliary control jets. The desired orientation of the second stage during the coasting flight is also maintained by the use of control jets. This stage, which acts as the launching platform for the third stage, must be properly oriented while the third stage is spun about its longitudinal axis prior to its launching. The third stage will then maintain its orientation parallel to the surface of the earth during burning.

An important component of the satellite orbital velocity is the more than 1,000 ft. per sec. the vehicle picks up because of the earth's rotational velocity at launch, provided, of course, the launch is in an easterly direction. The orbit, which results from all these maneuvers, is determined by the magnitude and direction of the satellite velocity at the end of third-stage burnout. Assuming that the altitude has been hit fairly close—that is, within 10 or 20 miles—a velocity tolerance of about 1 per cent (or 250 out of 25,000 ft. per sec.) and an angular tolerance of about 2.5 deg. are required to keep the satellite within the specified altitude limits of 200 and 1,400 miles. If the velocity is correct for a circular orbit, each degree of flight path error will cause the satellite to rise 75 miles and fall 75 miles at the highest and lowest point, respectively. If the flight path angle is correct, each 100 ft. per sec. velocity error will cause the orbit to rise or fall 70 miles, depending on whether the velocity is higher or lower than orbital velocity.[2]

### Special Radio Transmitter to Be a Tracking Aid

The satellite proper is currently thought of as a spherical body about 20 in. in diameter. It will be instrumented to carry out a program of scientific investigations which will not be discussed here.[3] In addition to its scientific instruments, the satellite will carry a special radio transmitter which will enable us to telemeter instrument readings and to track the satellite.

Electronic tracking will be used to point telescopes toward the satellite path so that the more accurate optical methods can be used to determine the orbit.[4] Since the projection of the satellite's path on the ground forms a wavy line extending from about 40 deg. North to 40 deg. South, a number of tracking stations will be used. These will form a chain of stations along the North and South American continents so that the satellite may be intercepted at least once on every passage around the earth.

The average taxpayer will have a fair chance of observing the satellite in its orbit if he lives in Baltimore or points south. All the equipment required is a pair of binoculars and some patience. The satellite should become visible if it is in the sunlight overhead while the observer is in the darkness of dusk or dawn. This condition will exist for only a few minutes.

### Satellite's Usefulness Depends on a Battery

Electrical power for the instrumentation will be supplied by a battery. The lifetime of this battery may well be the deciding factor in limiting the useful life of the satellite. The actual life of the satellite is determined primarily by the residual drag at the altitude of the orbit. The density of the air at these altitudes is not well known. The current estimates of the density might be in error by a factor of ten. Some recent estimates show that we can expect a drop in altitude in the order of 1,000 ft. per day for a circular orbit at 300 miles. At 200 miles, the drop will be 3 miles per day, while a circular orbit at 100 miles might result in a life of only a few revolutions.[5]

The motion of the satellite even without any drag will be complex. The irregular shape of the earth, and possibly also the irregular distribution of masses within it, will have a considerable influence on the orbit. Because of the oblateness of the earth, the orbital plane will spin around about 7 deg. per day, and the elliptical orbit will also revolve within its own plane at a rate of 1 or 2 deg. per day. The period of revolution of the satellite is also affected by initial conditions. Relative to the earth, the satellite will follow a somewhat sinusoidal curve as the earth revolves around its axis. During the 90 min. or so it takes the satellite to complete a revolution around the earth, a point on the earth's equator will have moved about 1,400 miles relative to the orbit. Therefore, a satellite which passes directly overhead will, on the next pass around the earth, be seen near the horizon.

At this point, it seems appropriate to turn to the things beyond the horizon, to the style trends in space ships.

### The Age of Bigger Satellites

One might reasonably prophesy that after Vanguard we will have bigger and better unmanned satellites: bigger, or rather heavier, so that they can carry more elaborate instrumentation; better in the sense that the performance of the launching vehicle will allow us more flexibility in the choice of orbits. In the field of increased performance, one must also include the capability to make corrections in the orbit by the use of auxiliary propulsion means after an orbit has been established.

For these satellites of the relatively near future, a number of uses have been proposed in addition to that of being a space laboratory for scientific observation.[6] Practical usefulness, which means simply that the benefits are obvious even to a layman, includes such things as using the satellite as a weather observation station which peeks down upon the earth's cloud cover with photocells or television cameras. Another useful

application might be as radio and television relay stations, either of the passive type—i.e., as a reflector—or of the active type with a transmitter in the satellite. Quite obvious difficulties exist in this application.

A reflecting passive satellite is extremely reliable simply because it has nothing to do except stay up there. Unfortunately, if one hopes to get away with a moderate, or even practical, amount of transmitted power, the satellite must be quite low, and a low satellite does not stay in one place very long. A satellite at 22,000 miles stays comparatively still, but the distance is so great that an active transmitter is required in the satellite which, in turn, cuts down reliability. In any event, we would have quite a severe controls problem if some definite antenna orientation is desired in the satellite vehicle.

A proposed satellite application is ASTRO, which stands for Artificial Satellite Time and Radio Orbits, an all-weather navigational aid of the future.[7] This satellite will carry a small atomic-powered radio transmitter. A navigator with a radio receiver can then determine his position on earth or in the sky by observing the doppler frequency from a triplet of these satellites and correlate his time of sighting with a special almanac made for the purpose. In view of the irregularities of the satellite orbit mentioned before and the difficulties in making measurements to the required precision, it is obvious that a good number of years will pass before we see the realization of these schemes. Yet the space enthusiast will state that we are merely at the beginning of our anticipated conquest. However, before we take off for outer space, it might be well to pause for a reconsideration of our current status.

## Manned Space Flight

Project Vanguard represents the current state of development. We can send up a rocket to establish an artificial satellite around the earth without causing an undue drain on the country's technical or economical resources. We can also send up a satellite ten times as heavy or ten times as far out without requiring any radical changes in the state of the art. However, when we start talking about interplanetary travel and manned space flight, even in an earth satellite, we reach beyond our present capabilities.

Man, when considered as a functional machine, has two main advantages: that of being readily mass produced by unskilled labor and that of being able to store and handle vast amounts of information in the small space of his brain. The price we pay for utilizing this fragile device is the creation of a highly complex and well-controlled environment in which it can operate in a satisfactory manner. Also, man is not generally expendable and therefore not available for unlimited experimentation.

Even to propel a 175-lb. man into a Vanguard orbit, giving him 175 lbs. of protective gear and 25 lbs. of instruments—i.e., a pay load of 375 lbs.—would require a gross take-off weight of 375,000 lbs. if the Vanguard ratio of about 1,000 between take-off weight and pay load applies. This is, needless to say, a rather big rocket, and even at that our space man would be somewhat dismayed to find that after all that expenditure of energy and money he could not return to earth.

## The Moon Rocket

Interplanetary travel also requires large rockets. To escape from the earth, a velocity of 35,000 ft. per sec. is required, or about 1.4 times the velocity of the Vanguard satellite. Once this velocity is attained, one could, in principle, travel to any place in the universe if no other force intervenes. It has recently been estimated that a pay load of 100 lbs. could be put on the moon with a 150,000-lb. three-stage rocket.[8] This pay load would hit the surface of the moon at 9,000 ft. per sec. and thus add to the already abundant supply of craters at this locality. If a braking action is desired during the descent to the moon, so that the impact is at essentially zero velocity, about 550 lbs. of braking rocket and fuel are required. With this equipment added, the gross take-off weight of the launching rocket would be about 950,000 lbs. Incidentally, the trip would take almost 3 days.

This example points to the core of the problem. We can with our present technology reasonably expect to sprinkle our solar system with small inert masses, but to go beyond this and really do something worth while is an entirely different proposition, involving not only problems of rocket propulsion performance but also equally staggering problems of control, navigation, and communication.

Let us now pose the question, "What should the next step be after unmanned earth satellites?" The two possibilities are manned space flight and unmanned flights outside the earth's influence (such as to the other planets).

Unmanned and automatic flights are undoubtedly the easiest, the problem being primarily one of controlling the flight of the vehicle. These flights will at first be made with chemical-type rocket drives. Any other type probably will have to be assembled from a space platform revolving in an orbit around the earth. This assembly requires the presence of human beings there and can therefore be accomplished only after we learn to live in space.

## The Role of the Navigator

Most of the velocity needed to go anywhere must be acquired in one big burst so that the navigational problem essentially becomes one of starting out in the right direction to begin with. This is indeed a peculiarity of ballistic rocket guidance. Once the velocity vector has attained the required magnitude and direction, the navigator's job is presumably done and he can relax and serenely watch the worlds pass by. The accuracy requirements are, however, quite severe. In the case of the moon rocket, the direction must be right to within about 0.5 deg. The velocity magnitude must be correct to within about one tenth of 1 per cent, or

about 35 ft. per sec. out of a total velocity of 35,000 if it is to hit the moon at all.

It is interesting to note that an intercontinental ballistic missile, which has a range of about 5,000 miles, must have a cut-off velocity on the order of 22,000 ft. per sec. and rise to an altitude of about 700 miles. For such a missile, an error in cut-off velocity of 100 ft. per sec. will result in an impact error of about 100 miles. An error in flight path angle at cut-off of 1 deg. will result in an impact error of about 25 miles.

For the moon rocket, one cannot rely entirely on the initial guidance but must have means available for exercising control along the flight path. These means of control could be chemical propellant rockets. These rockets are notoriously poor in their performance or specific impulse—i.e., the ratio of thrust to weight flow per second—because the velocity with which the rocket exhaust can be expelled is rather limited. One way of achieving better performance is by using nuclear energy to discharge streams of electrically charged particles at extremely high velocities in place of the chemical propellants. These charged particles, or ions, although they are extremely light, can be discharged at such tremendous velocities that their momentum is far from negligible. Although the propulsive efficiency of these ion drives is many thousand times higher than that of chemical rockets, the total thrust available is low. The thrust from an ion drive might not give the space ship an acceleration of more than 0.001 to 0.01$g$. As we see it today, it would be impossible to use this thrust device for take-off from the earth or any other planet or, for that matter, as a braking device when landing on a planet. However, once in free space one could use this small thrust to build up an increasing velocity over a long period of time. Such a ship would therefore be a valuable ferry for transfer between various orbits from which all descents would be made by "conventional" rockets and to which one would also ascend in a "conventional" manner. Mid-course navigation and control could be carried out by using the ion drive, although considerable care would have to be exercised. If, for example, the space ship is traveling along at a velocity of 35,000 ft. per sec., which is the minimum escape velocity from the earth, the turning radius with an available acceleration of only 0.01$g$ would be more than 725,000 miles in free space. To come to a complete stop from this velocity would take almost 31 hours, and the distance covered during this sudden stop would be about 360,000 miles. It is obvious, therefore, that some sort of emergency power for maneuvering is needed.

## Minimum Turning Radius

Under emergency power the turn could be made much sharper. The limitation on the maximum turning rate would be set by the human body's ability to withstand accelerations. If we set a limit of 3$g$ for a sustained turn, the minimum turning radius would be almost 2,500 miles, and the distance required to come to a complete stop would be 1,200 miles.

It is true, of course, that for interstellar travel the distance and time involved are so tremendous that units of days and thousands of miles do not seem large. One must, on the other hand, travel at tremendously higher speeds in order to get anywhere so that the difficulties in maneuvering are about the same. Regardless of the velocity with which one travels in space, the landing at the destination should be made with close to zero relative velocity.

One added complication in interplanetary navigation is that the destinations move around with considerable speed so that it is possible to become stranded in a celestial waiting room pending the arrival of the destination.

Now let us briefly consider manned space travel. Man has actually almost traveled in empty space. The high-speed research rocket airplanes have almost been there, although their velocity falls far below the required orbital velocity. It is not necessary though to travel at orbital velocity in order to stay up there. One can compensate for the lack of velocity by applying a lifting thrust. At half the orbital velocity, the downward thrust should be about three fourths of the vehicle weight, and at 0.9 orbital velocity the required thrust is about 0.2 of the vehicle weight, and so on. This mode of operation, recently referred to as a satelloid,[9] will presumably enable one to perform fairly well controlled practice flights in space near the earth. The difficult problem of re-entry could therefore be studied and valuable experience obtained in handling the navigation of space ships, while the problems of human survival and protection could be explored gradually.

Man's travel in outer space is naturally hazardous. Nature, which has provided so liberally for man on this earth, appears to be bent upon destroying him if he departs in the natural state from his habitat. Or maybe we should say that after millions of years of struggle through all stages of evolution to adapt himself to the earth's environment, man has suddenly found that he wants to go to a number of thoroughly undesirable places. We can only wonder why.

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*Emphasis on the urgent need for a high-strength corrosion-resistant steel for use in bomb-suspension equipment, in the light of the new requirements of modern aircraft.*

# Aircraft Armament Equipment*

## A Challenge to the Stainless Steel Industry

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### Introduction

This paper is concerned primarily with the metallurgical and material problems involved in the design, development, and manufacture of aircraft armament items. The hardware to be discussed is limited to the field of store launching devices. For the purpose of this paper, the term "store" is defined as a bomb, rocket, guided missile, fuel tank, torpedo, or any other container or shape carried and released during flight by military aircraft. Emphasis is put on the problems encountered in the use of and the requirement for the so-called "stainless" family of steels. However, data are also presented concerning other materials used in aircraft armament mechanisms.

### Background

During World War II, aircraft bombing systems and equipments received their first baptism under large-scale operating conditions. It is generally known that dropping stores from military aircraft proved quite efficient if massive destruction and the modern term "retaliation" are used as the basic criteria. The overall picture indicated that well-designed and efficient systems and mechanisms were used. However, those of us who were involved in the design, development, and maintenance of these mechanisms had many uneasy and disturbing moments caused by the difficulties arising from poor field maintenance, faulty production methods, and lastly, and sometimes most important, the inadequacy of the materials used in the various components of the aircraft bombing systems.

After World War II, the speeds, altitude missions, and other characteristics of military aircraft have undergone radical changes. With the advent of the jet age, speeds, altitudes, tactics, and new types of stores necessitated a complete re-evaluation of aircraft bombing systems. The separation problem arose. Stores no longer dropped away from aircraft under 1*g* conditions. It was found necessary to impart a separation velocity to the store in order to keep the aircraft from getting "clobbered." The accuracy and reliability of the holding and releasing mechanisms became a greater factor with the advent of the atomic age, which left very little or no margin for error. Guided missiles, rockets, high-speed fuel tanks, supersonic shapes, and all the other commonly known "Buck Rogers" devices have changed some of our thinking. It is necessary to reappraise what we now have, what we need to meet new requirements, and what our chances are of keeping pace with the rapid progress of aircraft during the jet age. In the design, development, and manufacturing of these devices, one basic problem has plagued us in the past and is still with us today. Basically, this problem concerns the use of high-strength, easily obtainable, corrosion-resistant, tough materials to be used in bomb systems and devices. This paper deals primarily with only one aspect of this material problem—the use of stainless steels.

### Specific Hardware

The first device to be discussed, which attempted to deal with the overall problem of strength, corrosion resistance, and reliability in bomb-dropping devices, was the Navy's Mk. 35 bomb rack. Fig. 1 is a photograph of the device which has proved to be the "daddy" of the bomb racks used during World War II and those in existence at the present time. As can be seen in Fig. 1, the item utilizes two hooks for the carriage and release of the store. The item was actuated by a manual cable which rotated the three-holed sector shown on the top center of the rack. In the late thirties, an electrical solenoid was mounted on top of

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the rack for remote-control actuation. The Mk. 35 is also of interest because the designer attempted for the first time to solve the newly arisen corrosion problem by the use of a stainless material. This entire bomb rack is made of monel. This metal, which contains approximately 70 per cent nickel and 30 per cent copper, was considered at that time to have high strength, hardness, and good resistance to corrosion. By today's standards, the characteristics of Monel are not as impressive. However, in 1935, the use of this material in a bomb-release device was quite an advance in the art.

Fig. 2 is a photo of the Monel hooks used in this rack. These hooks had a hardness level of approximately Rockwell C-17 which provided an allowable fiber stress of approximately 110,000 psi. This hook had an ultimate tensile strength of 10,000 lbs. The hook on the left of the figure shows the type of failure which occurs under this maximum load.

Work done on the Mk. 35 rack began to point up the basic requirements for bomb suspension hooks—namely, (1) high hardness in areas mating with the store suspension lugs, (2) high level of corrosion resistance to avoid corrosion fatigue and stress risers, and (3) high impact and fatigue strength due to aircraft maneuvers and vibration.

The Mk. 35 bomb rack weighed 18 lbs. and was designed to carry a maximum store weight of 500 lbs. The successor to the Mk. 35 rack was the Navy's Mk. 51, which was designed and developed during the 1939-to-1941 period. This rack was designed to carry a maximum load of 2,000 lbs. and weighed approximately 13 lbs. The Mk. 51 uses 1/16-in. thick 18-8 stainless-steel metal side plates joined into a box-frame structure by means of spot welding and rivets. In order to obtain the basic hook requirements of high strength, hardness, and toughness, the use of Monel was abandoned, and heat-treatable alloy steels were used. SAE 1040, cadmium-plated, was the hook steel used and was later abandoned because of corrosion and lack of uniformity of the material. The chrome-moly steels (SAE 4130), chrome-plated, were then incorporated in the design, and this type of hook was actually used in World War II. It is interesting to note that the Mk. 51, which did not utilize stainless steels for high-strength members, was capable of carrying four times the load carried by the Mk. 35 and yet weighed 5 lbs. less. It was apparent at that time that stainless steels were not available to meet the requirements for hook material. However, where strength was not a factor, the use of 18-8 stainless steels proved quite acceptable. The main difficulty encountered with the use of 18-8 was basically in the technique of fabrication, which in turn reduced itself to a quality control problem caused by spot welding and riveting operations. The ultimate strength of the hooks of the Mk. 51 rack, which are approximately of the same section as the old Mk. 35 using Monel, is 25,000 lbs. Thus, the saving in weight, when compared on the basis of strength, was considerable. Both the Mk. 35 and Mk. 51 racks were used on external-store carrying stations.

During the period in which the Navy developed the Mk. 51 rack, a parallel program was undertaken for the design, development, and manufacture of bomb shackles which were used principally in bomb bays during World War II in TBM, PB4Y, B-26, and B-29 type of aircraft. It was possible to design a much lighter mechanism than the two previous bomb racks discussed because of the nature of the bomb-bay installation whereby the loads were considerably lower and the method of mounting resulted in the loads being transmitted directly to the aircraft. Several shackles were produced during World War II utilizing 18-8 sheet-metal frames and stainless-steel linkages and components.

Fig. 3 is the Navy's Mk. 8 shackle which went into production near the end of 1944. This item weighed 7 lbs. and was capable of carrying and releasing 2,000 lb. stores. This shackle is of particular interest because an attempt was made to use type 416 stainless steel as the basic hook material. This was done to avoid what was then becoming an apparent problem in the use of chrome plating on bomb-rack hooks. Reduction of fatigue strength, the problem of hydrogen embrittlement, and the stress-concentration factor in the use of chrome plating first became apparent at the time, and thus the designers of the Mk. 8 shackle tried to avoid chrome plating by the utilization of a heat-treatable stainless steel. This attempt proved to be somewhat disastrous in that the type 416 stainless-steel hooks had an extremely high rate of corrosion, tended to work-harden, and were subject to frequent fatigue failures during service use. In order to avoid the corrosion problem, it was actually found necessary to chrome-plate this stainless material. The use of the 416 material was changed to the chrome-moly steels with chrome plating as the means of providing corrosion resistance, good bearing, and high-hardness characteristics. After this sad experience with 416 stainless for hooks, most bomb-rack designers abandoned the use of any of the martensitic, hardenable chrome steels for this application.

After World War II, the requirements for suspension devices changed radically, and several developments were undertaken for higher strength and reliable suspension and ejection devices. The following are data describing various racks and ejectors manufactured by the McLean Development Laboratories. These data again point up the urgency for the development of high-strength, stainless materials to meet the requirements for modern store suspension devices.

Fig. 4 is a photograph showing the parts breakdown of the Aero 65A, 14-in. bomb rack developed for the Bureau of Aeronautics, which is now being produced in quantity in our plant. The parts of interest in this rack are as follows:

(1) Frame—SAE 4140 chrome-moly steel bent into a U section, heat-treated to Rockwell C-39 to 42. No rivets or spot welding are used.

(2) Tie links—made of 18-8 stainless; latches—type 431 stainless steel heat-treated to 39 to 44 Rockwell.

(3) Hook pivot and other pins—type 431 stainless steel, Rockwell C-39 to 44.

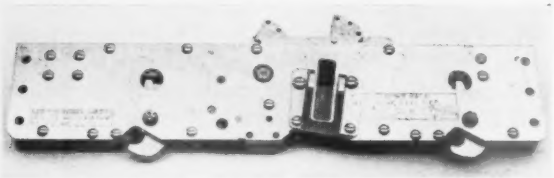

FIG. 1. Navy's Mk. 35 bomb rack—assembly.

FIG. 2. Mk. 35 bomb rack hooks.

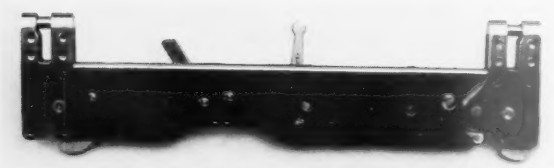

FIG. 3. Navy's Mk. 8 shackle—assembly.

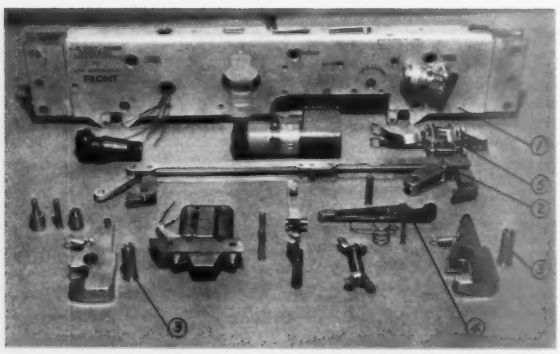

FIG. 4. Aero 65A bomb rack—exploded view.

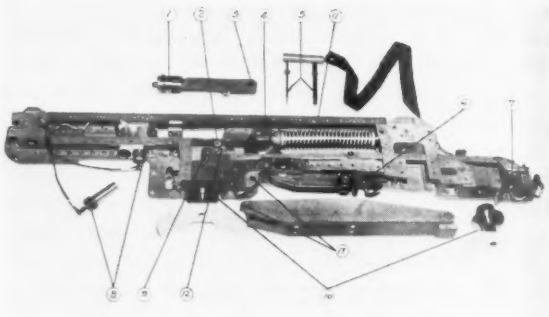

FIG. 5. Aero 22A ejector rack—assembly.

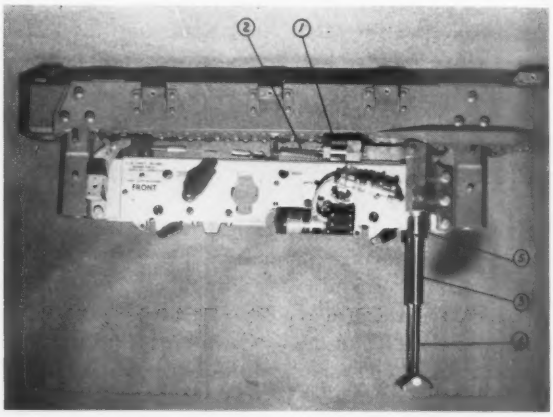

FIG. 6. Aero 23A store ejector—assembly.

65-005 HOOK
MATERIAL: 4140 STEEL
HEAT TREAT: ROCKWELL C-43-46
MINIMUM ULT. TENSILE: 200,000 PSI.

NOTES:

1. DESIGN ULTIMATE LOAD = 29,440 pounds AT POSITION "B"

2. ALL SECTIONS CRITICAL IN COMBINED BENDING AND TENSION WITH SOME SHEAR INVOLVED IN SECTION A. CALCULATED MARGIN OF SAFETY SLIGHTLY NEGATIVE AT SECTION C.

3. STRESS CONCENTRATION FACTOR ESTIMATED AT 1.2 AT SECTION C; CONSIDERED IN ELASTIC RANGE ONLY.

4. RESULTS OF STATIC TEST:

SPECIMEN #1: ROCKWELL C-43; FAILED AT 32,000 POUNDS AT SECTION A BETWEEN THROAT AND PIVOT HOLE. (This was old design; changed to larger radius to provide more material in region of failure.)

SPECIMEN #2: ROCKWELL C-45; FAILED AT 34,000 POUNDS AT SECTION C. HIGH FAILING LOADS DUE PRIMARILY TO SHIFT OF LOAD TO POSITION "B".

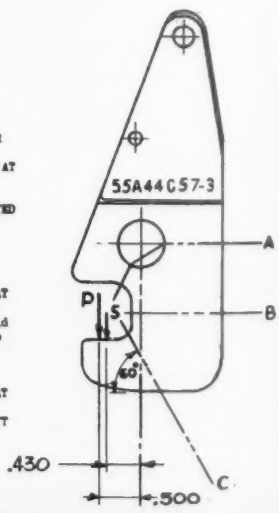


FIG. 7. Aero 65A hook—strength data.

(4) Latching pawl—beryllium copper for high strength, bearing, and corrosion-resistant properties.

(5) Electrical-release mounting strips—18-8 stainless-steel sheet.

Fig. (4) illustrates some of the highlights in the use of materials required for today's suspension device. The elimination of 18-8 side frames because of the fabrication difficulties and the higher strength requirements should be specifically noted.

Fig. 5 is a photograph showing the components of the Aero 22A ejector rack developed for Grumman's F9F-8 aircraft. This McLean device is also in mass production and represents the most modern explosive bomb ejector now in service use. Referring to Fig. 5, the following component parts are manufactured of some form of stainless material. (Numbers refer to those in photograph.)

(1) Piston—type 431 stainless.*

(2) Toggle pivot pin—type 431 stainless.*

(3) Connecting rod bushings—18-8 stainless and 416 stainless.*

(4) Yoke—type 431 stainless.*

(5) Safety pin—type 431 stainless.*

(6) Hook wiper plates—type 431 stainless.*

(7) Hook pivot pins—type 431 stainless.*

(8) Cartridge ignition caps—type 431 stainless.*

(9) Latch pin—type 431 stainless.*

(10) Swaybrace adjusting nut—type 431 stainless.*

(11) Shock absorber sleeve—18-8 stainless tubing, 1/4 hard.

(12) Toggle kicker plate—type 431 stainless.*

(13) Ejector arm bushing—type 431 stainless.*

It is apparent from the above breakdown that every attempt was made to use stainless materials in this design in order to avoid the many problems encountered when cadmium or chrome plating is used on highly stressed and moving parts. It should be noted that, on the highly stressed components such as the store suspension hooks, sway-brace posts, and crank arm, it was necessary to continue the use of chrome-moly steels with protective coatings of either cadmium or chrome and various paints.

Fig. 6 is a photograph of the Aero 23A store ejector now receiving Navy qualification tests. Here is a vertical type of ejector which makes extensive use of heat-treatable stainless steels. The following components are of interest.

(1) Ignition cap—type 431 stainless.*

(2) Secondary piston—type 431 stainless.*

(3) Primary ejection sleeve—type 431 stainless.*

(4) Secondary ejection piston—type 431 stainless,* changed to 4140, chrome-plated, during testing phase.

(5) Cylinder caps—type 431 stainless, changed to beryllium copper during testing phase.

One point of interest in the use of type 431 stainless in this application is that it was found necessary to chrome-plate various portions of the sliding members in order to avoid galling problems encountered in the use of stainless materials on sliding surfaces.

*Heat Treat: 175,000 psi min. (Rockwell C-39 to 44).

## Problems Encountered in Using Stainless Steel

We have extensively used type 431 stainless steel in the Aero 22A, Aero 23A, and Aero 65A store suspension devices. This was done after considerable investigation of 17-4-PH, type 410, and type 416 stainless materials. Our study resulted in the use of type 431 to obtain high strength and the best corrosion-resistant characteristics. However, the use of this material has not been completely satisfactory. The following are some of the existing problems:

(1) Procurement of 431 in small quantities for prototype development has always been a problem.

(2) It has been difficult to obtain the material in production quantities.

(3) Response to heat treatment for Class HT-175, has been very erratic. Specification MIL-S-18732 calls for a minimum ultimate tensile strength of 175,000 psi. We originally called for a hardness of Rockwell C-38 to 41 to correspond to this condition. All parts manufactured from bar stock for prototype passed this requirement. On production parts made from both bar stock and forgings, numerous pieces have come in as high as C-45 to 47, even after a 3-hour temper at 690°F. Detailed study of 431 indicated that C-39 to 44 should be the heat-treat callout for this material and the tempering temperature should be 600°F. However, tests of one item by bending to failure indicated a satisfactory outer fiber elongation of 14 per cent at a hardness of Rockwell C-47. We are reluctant to specify C-39 to 47 on our drawings since this could allow parts to be received and accepted in an "as quenched" condition.

(4) Obtaining 431 in a "free ferrite" condition.

Still encountered on production items in our plant are the following questions concerning type 431 stainless steel. (1) What is the proper austenitizing procedure to be used in order to obtain consistent results? (2) What is the optimum tempering temperature to obtain consistent results? (3) What are proper inspection procedures to control quality during the processing of this material?

As stated above, it has been necessary for Material Review Board action to require destruction of costly finished machined parts in order to obtain ductility and fatigue characteristics of large quantities of parts which are either slightly above or slightly below the hardness callouts on the detail drawings. This additional work and lack of consistency has caused serious production slowdowns from time to time.

The above discussion outlines some of the production problems in the use of generally available stainless steels. However, we have not as yet touched upon a fundamental requirement, which is the finding of a satisfactory stainless material for store suspension hooks. This is perhaps the most urgent need of designers and manufacturers in our field. The use of 4140 steel, chrome-plated, while doing a satisfactory job at the present time, leaves much to be desired. In order to point up some of the basic design problems in the

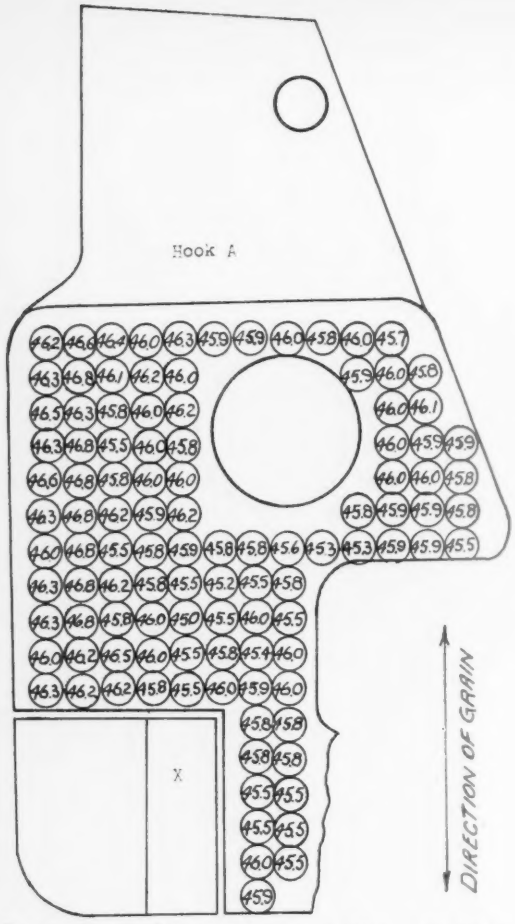


FIG. 8. Sketch of hook A showing variation of surface hardness, direction of grain, and location of microspecimen (Rockwell "C" readings in circles).

development of a store suspension hook, the following data are presented to acquaint the metallurgist with the characteristics of one of the most modern hooks—the hook now installed in the Navy's Aero 65A bomb rack shown in Fig. 4.

Fig. 7 is a structural drawing of this hook. Sections A, B, and C shown are the critical sections from the point of view of bending, tension, and shear strength. Most hooks in production at the present time and in the near future will have similar characteristics. It should be noted that the first hook specimen of this type which was tested failed at 32,000 lbs. through section A. By slightly increasing the radius of the throat in section A, it was possible to change the location of the weakness to section C and to increase the failing load approximately 2,000 lbs. This hook was actually designed to fail at 30,000 lbs. The fact that the item failed at 34,000 lbs. is attributed to load application shifting from point P to point S as the hook distorted under increasing load, thus decreasing the moment. In addition to the tensile characteristics shown in Fig. 7, work was done on this hook to determine fatigue characteristics. Two hooks were tested on a Sonntag fatigue tester which applied a positive load of approximately 2,000 to 8,000 lbs. at 1,800 cycles per min.

Hook A shown in Fig. 8 failed at very low fatigue life at 55,000 cycles.

Hook B shown in Fig. 9 could not be failed at all under the same fatigue test, and it was found necessary to terminate the test when a million cycles had been reached. Hook B was then taken to destruction in a Tinius Olsen machine and broke under a straight-down tensile load of 34,000 lbs., which basically showed that the hook was nowhere near failing in fatigue, even after 1 million cycles. It should be pointed out that both Hook A and Hook B (Fig. 9) were manufactured from bar stock which imposed a grain problem which is not as great a factor normally when forgings are used. Hook A failed in line with the direction of the grain. Hook B, which did not fail, had a grain flow which was 10° off the plane of maximum stress. This is pointed out to illustrate the sensitivity of these hooks under tensile and

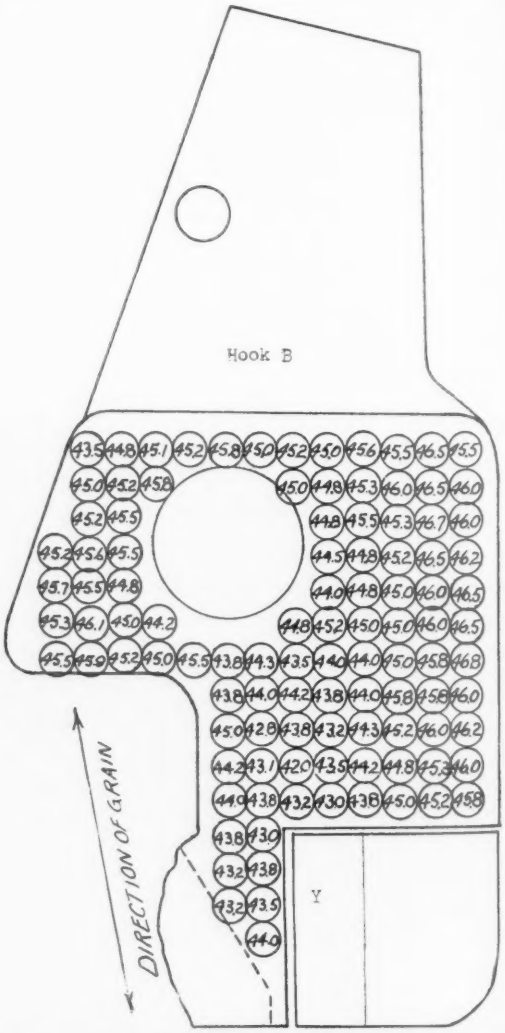


FIG. 9. Sketch of hook B showing variation of surface hardness, direction of grain, and location of microspecimen (Rockwell "C" readings in circles).

fatigue conditions which again shows the importance of proper processing and choice of materials for this component. Any stress riser, whether it is in the form of machine tool marks or cracks in chrome plating or of the existence of hydrogen embrittlement due to plating processes, can ruin a perfectly good hook design. Other factors such as variation in hardness levels and nonmetallic inclusions in the basic material are additional factors that affect the 100 per cent reliability necessary for a store suspension hook.

## Conclusions

Since this paper is being presented primarily to point up the problems and usage of stainless steels, the conclusions that the writer would like to make are centered about this type of material with little emphasis on other design problems in the equipment described above. It is hoped that the reader is left with a clear understanding that there is an immediate need for a stainless-steel material which can be used for hook type of components with the following characteristics:

(1) Strength: Ultimate tensile strength = 200,000 psi min. Yield tensile strength = 160,000 psi min. (Yield strength is normally more critical.)

(2) Hardness: Rockwell C-45 min. on lug bearing surface to prevent brinelling and galling.

(3) High toughness for both static and dynamic fatigue.

(4) Static creep endurance limit (ability to sustain a high static load indefinitely): 150,000 psi minimum.

(5) Sufficient corrosion resistance to obviate the need for additional coatings or platings.

(6) Avoidance of problems now encountered in stainless steel, such as intergranular corrosion, atmospheric corrosion, and pitting.

(7) Consistency of materials during heat-treating and general processing, which is required to avoid production slowdowns and situations on each batch of parts processed at different times in the same manner, yet resulting in seriously different characteristics.

(8) Ease of machining.

(9) Meeting the high skin-temperature requirements for supersonic flight.

(10) The large range of temperature characteristics from −70°F. to high-speed temperature of 300 to 500°F. during which the properties of the material are to remain fairly consistent.

(11) The availability of the material in small quantities for development work and larger quantities for production runs. This points up the use of critical materials which may not be available during a national emergency.

The above requirements are a serious challenge to the stainless-steel industry and are not beyond the realm of accomplishment. Unless we are missing a bet, our engineering staff knows of no stainless material that meets all of the above requirements. However, there are several steels which are rather close to accomplishing most of the points listed. It is believed that concentration of the industry on this problem can readily result in a quick and acceptable solution, a solution which is urgently needed to meet the present and future requirements of our armed forces.


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*A test program is described: Thin-walled shells were buckled by the axial impact of high-velocity masses. The mode of buckling failure in the dynamic case was significantly different from that in static tests. An empirical relationship for energy absorbed vs. impact velocity was found for one shell diameter-to-wall thickness ratio.*

# Dynamic Buckling Tests of Aluminum Shells*

Alfred F. Schmitt†
Ryan Aeronautical Company

### Symbols

$D$ = shell diameter
$E$ = material elastic modulus
$E.A.$ = energy absorbed
$E.Av.$ = energy available
$M$ = impacting mass
$Vi$ = impact velocity
$a$ = velocity of sound in material ($= \sqrt{E/\rho}$)
$b$ = axial length of shell specimen
$m$ = specimen mass
$t$ = shell wall thickness
$\lambda$ = half wave length of shell wrinkle
$\rho$ = material mass density
$\sigma_0$ = theoretical longitudinal impact stress
$\sigma_{cr}$ = static test critical stress

***Subscripts***

$DYN$ = dynamic
$STAT$ = static

### Introduction

THE PROBLEM OF THE complete dynamic collapse of structural members is of concern in investigations of the crash impact of vehicles. Of primary interest to the analyst are the magnitudes of peak loads (and hence, accelerations) developed, the character of the load-deformation relationship, and the energy absorbed by the member during deformation.

In one phase of a program of research into this problem, the dynamic collapse of aluminum shells was studied. As described herein, thin-walled, unstiffened aluminum shells were dynamically collapsed by the axial impact of a high-velocity mass. Axial compression was selected as representative of one of the major actions in survivable airplane crashes. The thin-walled

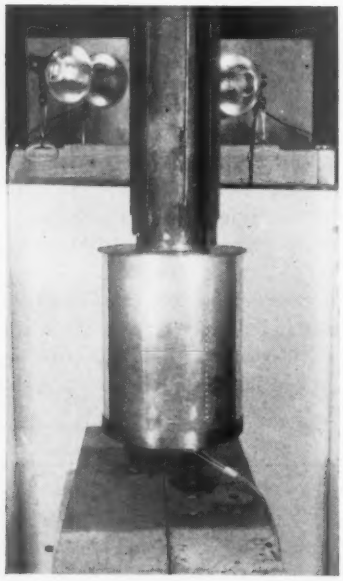

FIG. 1. A shell specimen positioned under the test jig. The dropping capsule is seen in contact with the upper bulkhead.

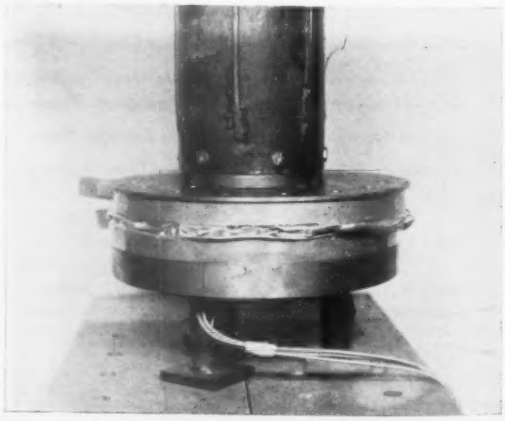

FIG. 2. A shell specimen immediately following a dynamic test.

* The work described was performed by the author while at Purdue University. The author wishes to express his gratitude to Prof. E. F. Bruhn of the Purdue University School of Aeronautical Engineering, under whose direction the test jig was erected and whose counsel in the conduct of the test program was invaluable. The work described herein was sponsored by the U.S. Navy, Office of Naval Research, under contract N7 onr 39416.

† Dynamics Engineer.

FIG. 3. Shell specimens as seen before and after testing.

shell was chosen as a basic element of contemporary aircraft structural practice.

## DESCRIPTION OF APPARATUS AND METHOD OF TEST

The test jig consisted of a 6-in. (nominal) steel guide tube, 21 ft. long, mounted vertically, with the lower end about 5 ft. above the laboratory floor. A steel frame and guy wires supported the tube, while a wooden framework was positioned for convenience in servicing. Either of two 5-in. diameter dropping capsules could be raised inside the guide tube to a predetermined drop height by means of a chain hoist centered over the top. Dropping capsule masses could be varied from 44 to 320 lbs. by the introduction of lead weights within the capsule. The maximum free fall impact velocity achieved was 371 in. per sec. A pneumatic boost system was also installed, by means of which impact velocities of 500 in. per sec. were achieved with a 200-lb. capsule.

Fig. 1 shows a specimen centered under the tube in test position. The ends of the cylinder were closed and supported by heavy steel bulkheads. The dropping capsule is seen in contact with the upper bulkhead—exactly the position which occurred in the dynamic test at the instant of impact. The position following a test is shown in Fig. 2.

All test specimens were 24ST Alclad aluminum and were fabricated by rolling two sheets, each the size of a half cylinder, and joining them by riveting two lapped seams on diametrically opposite sides of the shell. Fig. 3 is a "before and after" picture of the several shell types tested.

In the test program, slow "static" loadings were made on each size of specimen in a hydraulic testing machine while axial load vs. deformation was being recorded. Loading was continued through an axial travel nearly equal to the geometric length of the shell. A distortion of about 80 per cent of the geometric length was found to be the maximum "useful length" with the type of specimen mount employed; beyond this useful length the crushed material compacted together (bottomed), resulting in a "block compression" with subsequent high loads. The energy absorbed in such a test was computed as the integral of the load-deformation plot. Fig. 4 is a static test sequence photo.

In the dynamic tests, impact velocities were varied by using different drop heights and by the use of the pneumatic boost for highest velocities. Dropping capsule masses were also varied. In several series of tests (D, E, F in Table 1), the mass was adjusted before each drop so that the energy acquired by the capsule prior to impact was approximately equal to the energy absorptive capacity of the specimen (as determined by trial). In another test series (G), the capsule mass was held constant while impact velocity alone was varied.

A tripod load cell arrangement may be seen under the specimen in Figs. 1 and 2. Unfortunately, load signals obtained from these load cells were judged to be unreliable because of the dynamic response of the (relatively) flexible cells employed. Consequently, no data on dynamic loads are reported herein.

Dynamic energies absorbed by the specimen were computed from the changes in kinetic and potential energies of the dropping capsule in moving from a position just before impact (Fig. 1) to a position just prior to bottoming (roughly, the position of Fig. 2). Capsule velocities were obtained from a Fastax camera record showing the motion of a scale, fastened to the capsule, past a fixed hairline.

Another high-speed camera was employed to view the overall test action, giving a record of the mode of failure. Fig. 5 is a portion of a sequence of such pictures.

Additional details as to facilities and techniques are to be found in reference 1 and in the progress reports to the sponsoring agency.

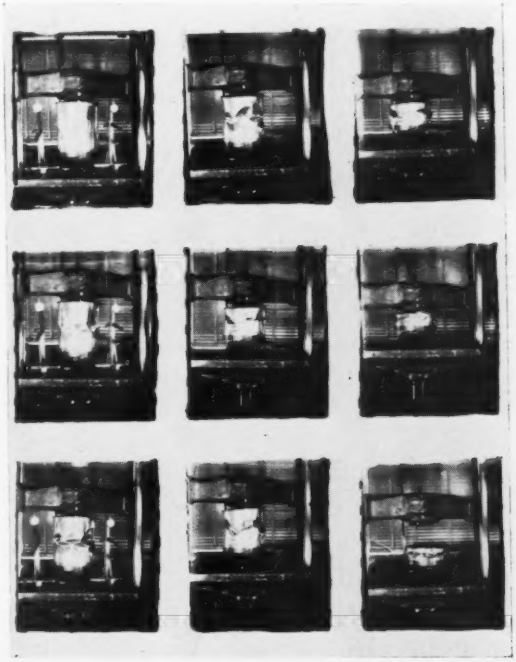

FIG. 4. A sequence of photographs of a static test.

TABLE 1
Shell Test Results and Other Data

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Ref. | Test No. | Impact Mass, lbs. | Impact Vel., ips | Energy Absorbed Dyn., in. lbs. | Energy Absorbed Static, in. lbs. | $\frac{M}{m}$ | $\frac{E.A.\ Dyn}{E.A.\ Stat.}$ | Energy Avail. in. lbs. | $\frac{E.A.\ Dyn}{E.Av.}$ |
| | | | | Series D, Dia. = 11", Length = 11", t = .020" | | | | | |
| 16 | 340 | 216 | 17,500 | 15,500 | 448 | 1.13 | | 22,700 | .77 |
| 15 | 278.5 | 312 | 28,000 | 15,500 | 366 | 1.8 | | 38,400 | .73 |
| 36 | 220 | 310 | 20,000 | 15,500 | 290 | 1.3 | | 29,200 | .68 |
| 17 | 190 | 371 | 27,000 | 15,500 | 250 | 1.7 | | 35,400 | .76 |
| | | | | Series E, Dia. = 11", Length = 11", t = .016" | | | | | |
| 37 | 220 | 209 | 12,600 | 11,100 | 361 | 1.13 | | 14,200 | .86 |
| 38 | 160 | 274 | 12,900 | 11,100 | 262 | 1.16 | | 19,700 | .66 |
| 39 | 101.0 | 333 | 11,400 | 11,100 | 166 | 1.04 | | 16,200 | .70 |
| | | | | Series F, Dia. = 11", Length = 5.5", t = .020" | | | | | |
| 35 | 220 | 208 | 12,000 | 9,170 | 733 | 1.3 | | 14,300 | .84 |
| 34 | 130 | 291 | 9,400 | 9,170 | 433 | 1.0 | | 15,100 | .62 |
| 45 | 160 | 275 | 14,000 | 9,170 | 533 | 1.5 | | 19,900 | .70 |
| 33 | 130 | 316 | 14,000 | 9,170 | 433 | 1.5 | | 21,800 | .64 |
| | | | | Series G, Dia. = 11", Length = 11", t = .016" | | | | | |
| 60 | 220 | 277 | 14,000 | 11,100 | 361 | 1.3 | | 24,200 | .58 |
| 50 | 220 | 295 | 16,700 | 11,100 | 361 | 1.5 | | 27,300 | .61 |
| 62 | 220 | 338 | 13,000 | 11,100 | 361 | 1.2 | | 35,200 | .37 |
| 51 | 220 | 358 | 18,000 | 11,100 | 361 | 1.6 | | 39,300 | .46 |
| 55 | 220 | 361 | 17,000 | 11,100 | 361 | 1.5 | | 39,900 | .43 |
| 59 | 220 | 365 | 11,000 | 11,100 | 361 | 1.4 | | 40,700 | .39 |
| 54 | 220 | 446 | 20,000 | 11,100 | 361 | 1.8 | | 59,900 | .33 |
| 64 | 220 | 476 | 18,000 | 11,100 | 361 | 1.6 | | 67,900 | .26 |
| 56 | 220 | 482 | 23,000 | 11,100 | 361 | 2.1 | | 69,700 | .33 |
| 63 | 220 | 497 | 21,000 | 11,100 | 361 | 1.9 | | 73,900 | .28 |

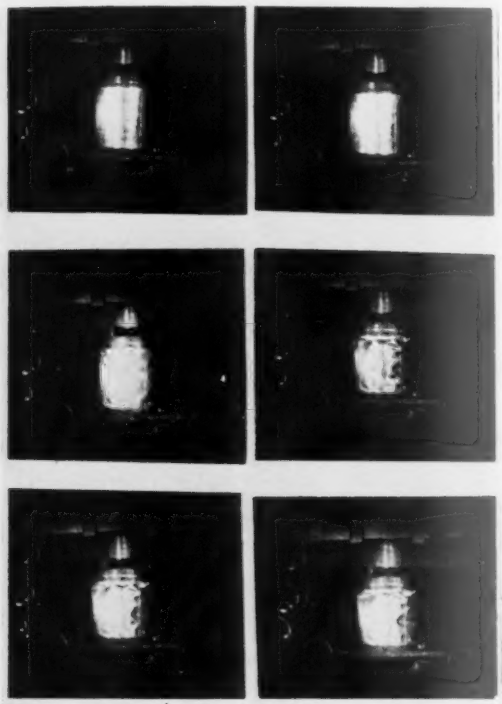

FIG. 5. A sequence of enlargements from a Fastax camera record taken during a dynamic test. These pictures do not represent successive frames from the film but rather were selected at regular intervals.

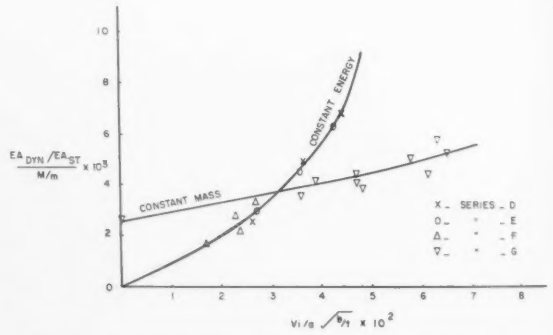


FIG. 6. Energy absorbed vs. impact velocity for 24ST aluminum shells, $D/t = 600$; energy reduced by use of static energy absorbed.

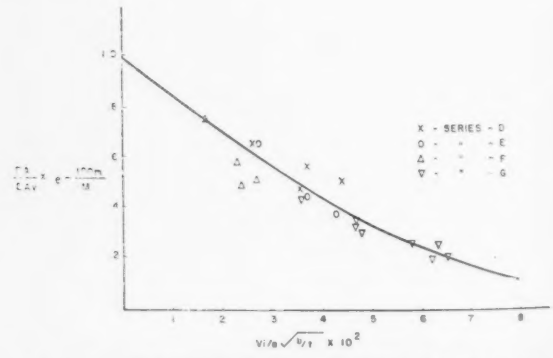


FIG. 7. Energy absorbed vs. impact velocity for 24ST aluminum shells, $D/t = 600$; energy reduced by use of energy available.

TABLE 2

Shell Wrinkle Wave Lengths as Approximated from Fastax Film Records

| $\lambda/t$ | $\sigma_0/\sigma_{cr}$ |
|---|---|
| 209 | 1.0 (static test) |
| 126 | 2.5 |
| 115 | 4.5 |
| 103 | 5.3 |
| 62 | 6.3 |

## RESULTS

Table 1 presents the results of dynamic and static tests on 26 aluminum shell specimens. The column headings are explained as follows:

*Impact Mass*—The mass of the dropping capsule plus that of the upper steel bulkhead (20 lbs.).

*Impact Velocity*—The velocity of dropping capsule plus upper bulkhead, assuming an inelastic impact occurred between these masses.

*Dynamic Energy Absorbed* ($E.A._{DYN}$)—Energy extracted from the impact mass in distorting the specimen 80 per cent of its geometric length.

*Static Energy Absorbed* ($E.A._{STAT}$)—Energy absorbed by static test specimens in a hydraulic testing machine; distortion of 80 per cent of geometric length.

$M/m$—The ratio of impacting mass to specimen mass.

*Energy Available* ($E.Av.$)—The kinetic energy of the capsule and upper bulkhead combination at time of impact plus the gravitational potential of these masses above the 80 per cent distortion position.

## ANALYSIS AND DISCUSSION

The most notable feature of the test results is the greater energy absorbed in the dynamic buckling of the shells as compared with the slow "static" loading. Table 1 shows this ratio to be greater than unity in all cases.

To understand the reasons for the variation with velocity of energy absorbed, a study was made of the high-speed movies showing the overall buckling action. Two important differences between dynamic and static tests were observed:

(1) In the dynamic tests, an initial wrinkle pattern developed almost instantaneously upon impact.* This pattern was general over the shell, unlike that formed in static tests wherein the wrinkles concentrated away from the supported ends (cf. Figs. 4 and 5). More importantly, the wave length of the wrinkle decreased with increasing impact velocity (and hence impact stress) as shown in Table 2.

(2) Collapse progressed not so much from a general growth of the initial wrinkle pattern as from a local deepening of the wrinkles and an intense crippling action occurring adjacent to the moving bulkhead. This action is to be seen in Fig. 5.

*"Instantaneously" is used here in contrast to a period of the order of milliseconds observed in tests on columns.[1] The velocity of travel of the first longitudinal loading wave down the shell is, of course, finite.

Final failure of the shell proceeded through a complex interaction of the two wrinkle systems discussed above. It is apparent that, the greater the degree of bending and twisting of the shell walls, the more work must be done in collapsing the specimen. If, therefore, one hypothesizes that a finer, more general initial wrinkle pattern will subsequently lead to a greater degree of bending and twisting during collapse, a primary reason for the increase in energy absorbed with impact velocity is established.

To explain the localizing of progressive crippling against the moving bulkhead, appeal may be made to the classical argument of the effect of end restraint. It is known that the effect of lateral restraint upon the ends of a cylinder in compression is to intensify the lateral deflections at the ends, so that (in the case of symmetrical crippling failure) failure actually appears to proceed from the ends (reference 2, p. 442).

Now for a slow, "static" loading, there would appear to be no reason for this crippling action to show a preference for one end of the cylinder, except for a possible difference in the degree of constraint. In the dynamic tests, this latter possibility was eliminated by several interchanges of the bulkheads, the crippling invariably occurring adjacent to the moving end.

Consider the instant in the dynamic test at which the complete cylinder has experienced the primary instability failure ("diamond" pattern). The wrinkles are well developed, and the net axial load is relatively uniform throughout the shell—the condition might correspond to the third frame of Fig. 5. The upper bulkhead now continues to advance. Intelligence of this action takes the form of a load increment which is carried ahead of the moving bulkhead by flexural waves, deepening the existing wrinkles. The velocity of the incremental load would be low, inasmuch as the net axial load exceeds the critical load, transverse deflections are large, and elastic failure of some of the material either has occurred or is imminent. Thus, the deepening of the wrinkles and the intense local crippling would not precede the moving bulkhead by far. In particular, the "tightness" of this local crippling against the moving bulkhead should be more pronounced for the higher impact velocities. This last conclusion was confirmed by examination of high-speed movies of the tests.

Following a dimensional analysis of the dynamic shell buckling problem, an attempt was made to reduce the dynamic energy absorbed data of Table 1 using the dimensionless ratios $E.A._{DYN}/E.A._{STAT}$, $M/m$, $Vi/a$, $b/t$, and $D/t$. Reduction of the dynamic energy absorbed data in terms of the static energy absorption seemed most desirable, since this latter quantity is readily obtained with modest test facilities.

Fig. 6 shows the result of plotting the best arrangement of these parameters found after much trial. The range of $D/t$ ratio used in these tests (550 to 688) was not sufficiently great to indicate any dependence upon this parameter, and hence it was not employed.

The data appear to divide into two distinct families, as indicated by the curves labeled "constant energy"

and "constant mass." The "constant energy" curve passes through the data of series D, E, and F in which capsule mass was varied to keep the capsule energy at impact about equal to the specimen absorptive capacity. (Actually, "constant energy" is a misnomer, but it may be used to describe the test technique employed.) The "constant mass" curve passes through the data points for series G in which the impact mass was kept constant.

The "constant energy" curve was projected down to zero at zero velocity since $M$, the "mass" of the machine used to conduct a static test, is very great. The "constant mass" curve was projected down to intersect the ordinate at

$$\left(\frac{E.A._{DYN}}{E.A._{STAT}} \times \frac{m}{M}\right)_{Vi\,=\,0} = 1 \times \frac{1}{361} = 2.77 \times 10^{-3}$$

$M/m = 361$ being the constant mass ratio used in these tests.

The appropriateness of these curves seems assured. But then it is obvious that a different curve is needed for each "constant mass" test in which the $M/m$ ratio differs from 361; and, further, no curve of this family will agree with the "constant energy" curve. Thus, it appears unlikely that the parameters employed in Fig. 6 can successfully reduce all the test data to a common curve.

Fig. 7 shows a plot of all the test data in which the dynamic energy absorbed has been reduced by division by the *energy available* in the impacting mass. The energy available is defined as the kinetic energy in the impacting mass at impact plus its potential above the 80 per cent compacted position. As may be seen, this fortuitous choice of parameters successfully reduces the data of all tests. The mean deviation from the curve is well within the experimental error. The curve is drawn from unity at zero velocity, approaching zero asymptotically for high velocities; these limiting values agree with rational expectations.

The parameters used in reducing the test data for Fig. 7 would appear to be more generally useful than those of Fig. 6. With such a curve, it is possible to predict the energy absorptive capacity of an aluminum shell under impact by a given mass at an assigned velocity. Some limitations on this plot must be noted:

(1) It is applicable only to aluminum, although the presence of the material sonic velocity in reducing the impact velocity may make it more generally applicable.

(2) It is applicable to shells of only one diameter-to-wall thickness ratio—about 600, since the range of $D/t$ values in this test was between 550 and 688, a variation too small to yield a noticeable $D/t$ influence. Further testing is required to determine whether shells of other materials and other $D/t$ ratios will similarly reduce. A modification in the reduced velocity parameter seems a possibility, as does the use of family curves—one for each $D/t$ ratio.

## Conclusions

The following conclusions are drawn as a result of the test program described herein:

(1) The energy absorbed in the dynamic axial buckling of a pure shell is greater than that absorbed in slow, "static" collapse. The ratio of these energies increases with increasing impact velocity over the range of velocities tested (up to 500 in. per sec.) and probably beyond that, through any range of velocities normally anticipated in vehicle crashes.

(2) Under dynamic impact, an initial instability pattern develops rapidly following impact. The failure mode is of the same diamond pattern as experienced in static tests but is developed uniformly over the entire shell. The wave lengths of these initial patterns were found to decrease with tests of increasing impact velocity.

(3) The increase in energy absorption with velocity of impact may be explained by assuming that the finer, more general instability pattern developed under impact will result in more material being affected by bending and twisting during subsequent collapse.

(4) As failure progresses during a dynamic test, an intense local crippling action develops adjacent to the moving bulkhead, with the bulkhead appearing to "chew its way" along the specimen.

(5) Energy absorbed data from various dynamic tests may be successfully reduced by use of the parameters of Figs. 6 and 7. The parameters of Fig. 7 appear to be more generally useful, although it remains to determine the influence of material modulus and $D/t$ ratio, the curves given having been obtained only for aluminum shells of $D/t = 600$.

## References

[1] Schmitt, A. F., *A Study of the Dynamic Ultimate Energy Absorption Characteristics of Structural Elements*, Doctoral Thesis, Purdue University, 1953.

[2] Timoshenko, S., *Theory of Elastic Stability;* McGraw-Hill Book Company, Inc., New York, 1936.

*A review is made of the manner in which jet-stream interactions affect thrust and drag of various nozzle installations.*

# Some Aerodynamic Considerations of Nozzle-Afterbody Combinations

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Lewis Flight Propulsion Laboratory, NACA

## Symbols

| | |
|---|---|
| $A$ | = area |
| $D$ | = drag |
| $H$ | = total pressure |
| $M$ | = Mach Number |
| $M_{1j}$ or $M_{2j}$ | = Mach Number of separated jet flow just upstream of trailing shocks |
| $M_{1s}$ or $M_{2s}$ | = Mach Number of separated stream flow just upstream of trailing shocks |
| $m$ | = mass flow rate |
| $p$ | = static pressure |
| $q$ | = dynamic pressure |
| $V_B$ | = velocity of bleed air in plane of base |
| $\overline{V_I}$ | = average velocity of bleed air in plane of inlet |
| $\beta$ | = boattail angle, deg. |
| $\gamma$ | = ratio of specific heats |

*Subscripts*

| | |
|---|---|
| $B$ | = base |
| $I$ | = bleed air condition at plane of auxiliary inlet |
| $j$ | = jet conditions in plane of nozzle exit |
| $M$ | = maximum body |
| $N$ | = nozzle exit |
| $T$ | = nozzle throat |
| 0 | = free stream |

## Introduction

THE AERODYNAMIC PROBLEMS associated with propulsion-system installations have assumed a role of vital importance in the development of supersonic aircraft. Although air-induction systems have received moderate attention in the literature, considerably less information can be found on the design and installation of turbojet exit nozzles. This condition should not be interpreted to indicate a lack of problems in jet-exit design.

As flight speeds reach supersonic levels, it becomes increasingly difficult to achieve nozzle installations which are efficient over the entire speed range. The difficulties largely stem from the fact that the goals of high jet thrust and low afterbody drag are not always compatible. In many of the compromise solutions, it is generally unsatisfactory to examine isolated nozzle and afterbody performance. Rather they must be treated as a unit, and the complex effects of jet interaction with the external stream must be taken into account. To accomplish this, the nozzle and air-frame designers must closely coordinate their efforts.

Some of the aerodynamic problems of nozzle-afterbody combinations are outlined in this report. Particular attention is devoted to the influence of the jet-stream interaction on both nozzle thrust and afterbody drag. For this purpose, use is made of shock-boundary-layer-interaction concepts. This approach, although not precise, correctly predicts many trends and is generally enlightening.

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## Nozzles

### *Requirements*

It is first necessary to understand why operation over a wide speed range can be such a severe physical requirement for a nozzle. This is illustrated in Fig. 1. As flight Mach Number increases, increasing ram pressure results in an increasing ratio of jet total pressure $H_j$ to free-stream static pressure $p_0$. Optimum thrust by conventional definition requires that the high-pressure jet air be expanded internally to free-stream static pressure. To do this, the nozzle-exit area must become increasingly larger than the throat area as speed increases, as indicated in the lower portion of the figure.

If the nozzle exit area is less than ideal, the flow is said to be underexpanded. In this condition, some thrust is lost by the failure to provide additional nozzle area over which pressures higher than ambient might be maintained. If the nozzle exit area is greater than ideal, the flow is said to be overexpanded. In this

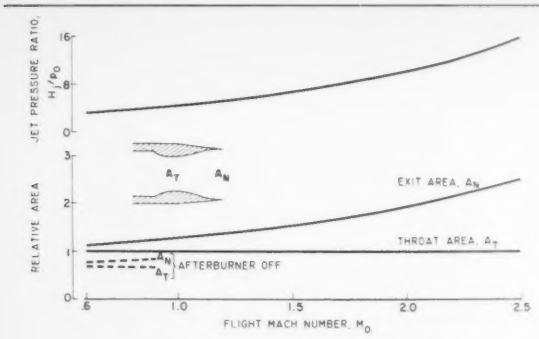


FIG. 1. Nozzle requirements.

condition, static pressures below ambient occur in the downstream portion of the nozzle which also creates a condition of thrust loss. It is thus clear that a nozzle with a fixed ratio of exit to throat area can yield optimum thrust only at one pressure ratio or flight Mach Number.

The throat area itself, with constant afterburner temperature, varies only slightly for most engines. When the afterburner is turned off, however, a large reduction of both the throat and exit areas is required.

### *Types*

Various nozzle types have been evolved to satisfy these internal-flow requirements. Some of these are shown in Fig. 2 with some typical installations. The convergent nozzle satisfies the requirement of throat-area variation by the use of a single set of hinged elements as indicated. Large thrust penalties are encountered at supersonic speeds, however, because of the failure of this nozzle to provide internal expansion. The variable convergent-divergent nozzle provides a second set of elements in order to provide variable internal expansion. Although this nozzle meets all of the requirements of Fig. 1, it is mechanically complex since the two sets of hinged elements are connected.

A slightly less complex nozzle which provides both throat and expansion control is the ejector nozzle. The principle of operation of this nozzle is as follows:

The primary jet flow expands from the throat to the wall formed by the secondary shroud elements. By so doing, it restricts the flow of secondary air thus permitting the secondary passage to be pressurized by the secondary flow. Maintaining static pressures above ambient static in the secondary passage is roughly equivalent to maintaining the average pressure above ambient on the diverging wall of a convergent-divergent nozzle. Thrust greater than that of a convergent nozzle is thus realized.

The plug nozzle places the expansion surfaces on the inside of the jet flow. Throat-area variation may be provided with hinged flaps. Disregarding external-flow effects, no variable divergence is required since, in the absence of confining nozzle walls, the jet flow adjusts automatically to compensate for changes in jet pressure ratio. The limitations of this assumption will be discussed later.

### *Installations*

The requirements that the variable nozzles place on the external flow depend on the external fairing lines, as well as on the nozzle variations. Various fairing types are also illustrated in Fig. 2. In general, all fairing types may be considered for any one of the nozzles. The long fairing illustrated with a convergent nozzle overhangs the nozzle flaps and creates a blunt annular base. The base size varies as nozzle-throat area is varied. In the case of a short fairing, the rearmost external contour is formed by the nozzle flaps themselves. The steepness of the flaps is dependent on their length and required area variation and may effectively approach a blunt base under some conditions. A variable fairing is shown combined with a variable convergent-divergent nozzle. If long variable elements are used for the fairing and the divergent portions of the nozzle, this installation appears to represent about the best that can be done from a thrust-minus-drag viewpoint.

The various fairing types may be encountered in both fuselage and nacelle installations. Fuselage installations differ from nacelle in that boattailing usually precedes the base and creates a somewhat different flow environment in which the nozzles must operate. In view of the many possible nozzle-afterbody combinations, it is evident that a wide variety of flow conditions may be encountered.

## Boundary-Layer Separation Concepts

The concept of peak pressure ratios for separated turbulent boundary layers is a great aid to understanding many of the flow fields encountered. Calculations based on this concept constitute a major portion of the remainder of this paper. Consider the forward-facing step [Fig. 3, sketch (A)]. At supersonic speeds for inviscid flow, the step creates a bow shock wave ahead of it. Above some lower limiting Mach Number, the pressure ratio across the shock wave is sufficient to

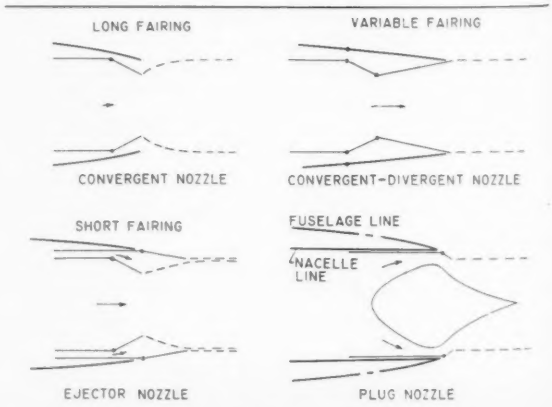


FIG. 2. Nozzle installations.

separate the boundary layer which is present in real fluids. A steady separated flow is then established with the bow shock replaced by an oblique shock. For turbulent boundary layers, the peak static-pressure-rise ratio resulting $p_2/p_1$ is a nearly unique function of Mach Number ahead of the shock $M_1$. This phenomenon has been studied by numerous investigators with much more attention to detail than can be considered here. References 1 and 2 present summary data and bibliographies of both experimental and theoretical work in this area.

It may further be shown[3] that the separated flows behind rearward facing steps [Fig. 3, sketch (B)] and blunt base airfoils [Fig. 3, sketch (C)] reattach with peak pressure ratios roughly comparable to those obtained with the forward facing step. The shaded area of Fig. 3 in general covers the scatter of data for conditions indicated in sketches (A), (B), and (C).

In considering nozzle-afterbody combinations, two qualitatively similar phenomena are at once recognized. When a nozzle is overexpanded, the wall static pressures drop below the external static pressure into which the flow is discharging. The pressure rises to the discharge value by the mechanism of an oblique shock wave. When the pressure ratio across the oblique shock $p_2/p_1$ exceeds some limiting value, the flow separates in the nozzle [Fig. 3, sketch (D)]. If there is external flow, the two streams meet in a manner similar to the blunt-base airfoil, and some peak pressure ratio is also established at this point. Knowledge of the peak pressure ratio in the nozzle permits estimation of the nozzle separation characteristics. Knowledge of the peak pressure ratio downstream of the base permits estimation of the base pressure [Fig. 3, sketch (E)]. Where nozzle separation exists with external flow, the solutions must be simultaneous.

Some important differences exist which limit the accuracy of applying the data of cases (A), (B), and (C) to the analysis of problems (D) and (E). First, peak pressure ratios are a function of the state of the boundary layers negotiating the pressure rise In nozzle installations, as contrasted with the two-dimensional cases (A), (B), and (C), the boundary layer of

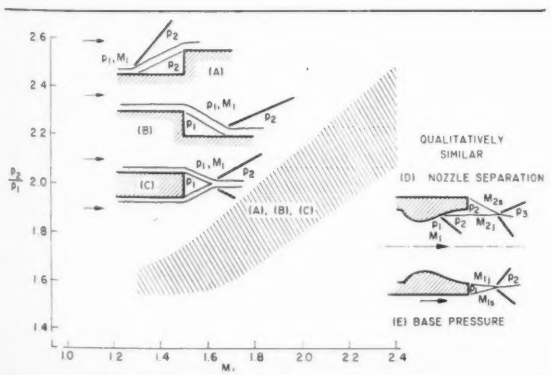


FIG. 3. Peak pressure ratios for separated turbulent boundary layers.

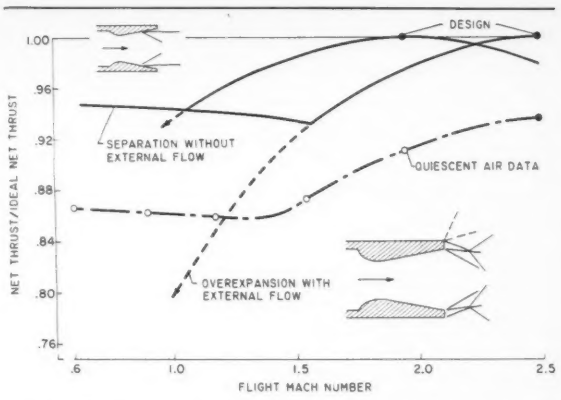


FIG. 4. Convergent-divergent nozzle characteristics; $\gamma_i = 1.4$.

the jet traverses a favorable pressure gradient in the nozzle prior to separation and may have heat extracted from it by cooling. The external flow negotiates the complex pressure field of the body. Thus, neither of the boundary layers is apt to have a turbulent flat plate profile prior to separation. In addition, where the two streams interact, they are at different levels of temperature, total pressure, and Mach Number and are generally curved as a result of the three-dimensionality of the flow. Despite these differences and other basic limitations of this empirical approach, the data of Fig. 3 satisfactorily predict some important trends in the problems of the nozzle-afterbody combinations which have already been introduced. The data have been applied to this end in several of the following figures.

## NOZZLE CHARACTERISTICS

### *Convergent-Divergent Nozzle*

Consider first the thrust characteristics of nozzles and how they can be influenced by an external stream. Although an apparent need for variable geometry was indicated in Figs. 1 and 2, design compromises make it worth while to look at the off-design performance of fixed geometry nozzles. Fig. 4 presents the calculated ratio of net thrust to ideal net thrust for two convergent-divergent nozzles over a range of flight Mach Numbers. Afterburning flight at constant altitude is assumed, and thrust loss due to wall friction is neglected. The nozzle designed for a flight Mach Number of 2.5 experiences overexpansion losses as flight speed is reduced. At slightly below Mach 1.6, the data of Fig. 3 would predict the flow to separate, thus preventing overexpansion losses from exceeding 7 per cent. The thrust (including friction) obtained experimentally with a 24° included-angle nozzle having an unheated jet is shown roughly to verify the predicted trend, although nozzle-exit angle materially affects this correlation. With external flow, however, the base pressures calculated with the data of Fig. 3 indicate that the flow would remain unseparated down to at least Mach 1, the limit of the calculations. The resulting

thrust losses are seen to be prohibitive. The nozzle designed for about Mach 2 operation shows slight losses above its design point but much improved performance below. Separation neglecting stream effects would again limit the overexpansion thrust losses to less than 6 per cent. The additional overexpansion due to stream effects in the subsonic flight region is not calculable.

In the foregoing calculations, the base was assumed for convenience in order to space the successive internal shocks, and base drag was not charged against the nozzle. It should be noted that any alteration to the external geometry which would increase the base pressure, such as the presence of a boattail, would advance the separation point toward the quiescent air value.

### *Plug Nozzle*

The plug nozzle in quiescent air does not require separation to maintain high thrust levels during off-design operation because the flow is not confined. However, external flow effects can make the plug nozzle even worse than the fixed convergent-divergent nozzle in some installations. This is illustrated in Fig. 5 where the method of characteristics has been combined with the data of Fig. 3 to predict the performance of a two-dimensional plug nozzle. The performance neglecting external stream effects will be considered first. At the design point of $M = 2$, the thrust equals the ideal value as did that of the convergent-divergent nozzle. At higher speeds and pressure ratios, the underexpansion losses again equal those of the convergent-divergent nozzle. At reduced speeds, the jet expands only to ambient pressure on the plug surface, and this expansion is followed by compression waves as the jet is turned further in the axial direction. Thus, disregarding stream effects, thrust losses do not exceed $1^1/_2$ per cent. In the real case with external flow, however, extremely low pressures are predicted on the base of the high angle flap by the data of Fig. 3. The jet expands to this low base pressure, and, for this case, the nozzle suffers the same overexpansion losses as the equivalent convergent-divergent nozzle. The plug nozzle would be expected to exhibit performance closer to that predicted from quiescent-air calculations if installations behind an axially symmetric boattail resulted in base pressures closer to ambient.

The steep flap angle is required for an ideal all-external expansion nozzle. If the flap drag is charged against the nozzle, the adverse stream effects are seen to be far in excess of those for the fixed geometry convergent-divergent nozzle, which ideally does not require a base.

### *Ejector Nozzle*

The last to be considered is the ejector nozzle (Fig. 6). As mentioned earlier, this nozzle achieves thrust in excess of a convergent nozzle by pressurizing the passage around the primary nozzle with secondary flow. The nozzle must, of course, be charged with the inlet momentum of the secondary air. In the sketch of Fig. 6, this air is shown coming from auxiliary inlets located in the boundary layer, although, for the calculated curves, free-stream air was considered to be the source. The curves were calculated by a theory devised by F. D. Kochendorfer; an early form of this theory may be found in reference 4. The calculation predicts thrust levels for optimum (on design) ejectors which lie about midway between the convergent and ideal nozzles. The fixed-geometry ejector falls off in performance relative to the envelope of best ejectors both above and below its design point. Although not clearly evident from this figure, the fixed geometry ejector shows less tendency to overexpand than the convergent-divergent nozzle. Stream effects on overexpansion were not estimated because this particular ejector is not subject to them in the speed range where they might be calculated. It should be noted, however, that matching the auxiliary inlet air handling characteristics to the ejector requirements constitutes a form of nozzle-stream interaction not present with the previously discussed nozzles.

The thrust levels in Fig. 6 should not be compared with those of Figs. 4 and 5 since an allowance is made for friction only in the case of the ejector. In addition, the ejector is inherently cooled, whereas the other nozzles are not and are not charged with cooling drag.

In summary, it would appear that stream interference effects can play an important role in determining the off-design performance of the nozzles discussed under some conditions. The jet interference effects on the external flow will now be considered.

## Jet Effects on Flow over Boattails

Jet interference on boattail pressures is illustrated in Fig. 7 for a simple combination of conical boattail and convergent nozzle. The flow over the boattail is characterized by an expansion at the start of the boattail followed by compression toward ambient pressure. The second-order linearized theory of Van Dyke[5, 6] is seen to describe adequately the flow neglecting jet effects. At the rear of the boattail, the flow is deflected by the jet. The higher the jet static pressure, the more the jet "billows" out and deflects the external flow. For inviscid flow, the deflection would produce an oblique shock with a discontinuous rise in pressure in the external stream. The presence of the boattail boundary layer does not permit a discontinuity in pressure, however. Instead, the pressure rise "feeds back" through the boundary layer, and the rise begins with compression waves originating ahead of the base. This phenomenon is illustrated by the data obtained at Mach 1.9. For trailing shock waves of sufficient strength, the boundary layer will separate forward of the end of the boattail.

The effect of the increased pressures on the boattail is a reduction in boattail drag as illustrated in Fig. 8. The largest reduction was experienced by the steepest boattail. Also shown on the figure are drag reductions

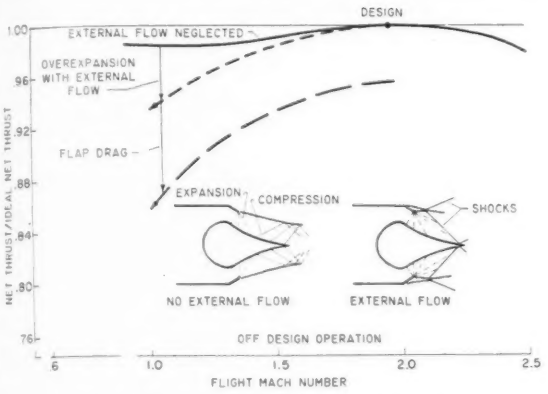


FIG. 5. Plug nozzle characteristics; $\gamma_j = 1.4$.

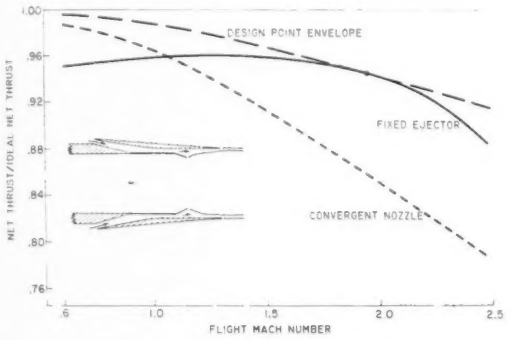


FIG. 6. Ejector nozzle characteristics; Kochendorfer theory ($\gamma_j = 1.3$).

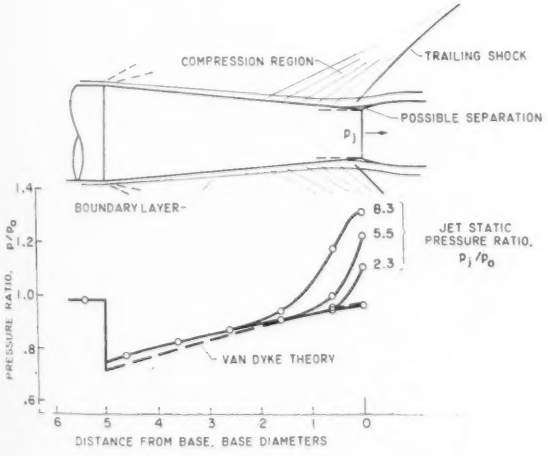


FIG. 7. Jet effects on boattail pressures; $M_0 = 1.9$, $\gamma_j = 1.4$.

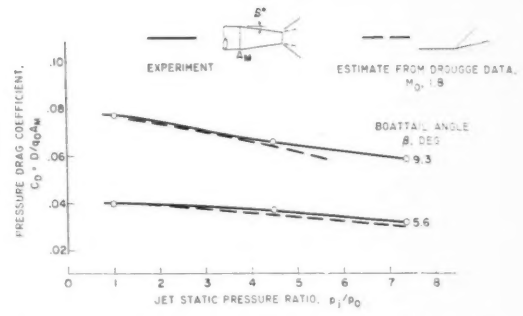


FIG. 8. Jet effects on boattail drag; $M_0 = 1.9$, $\gamma_j = 1.4$.

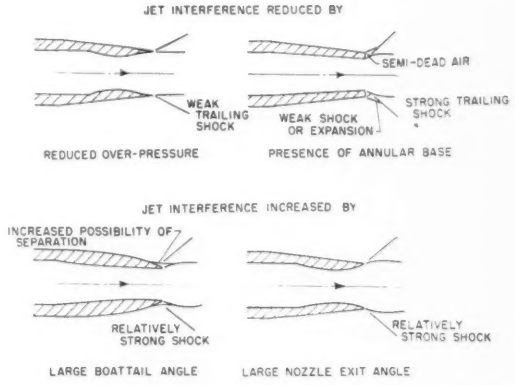


FIG. 9. Factors modifying jet effects on boattail pressures.

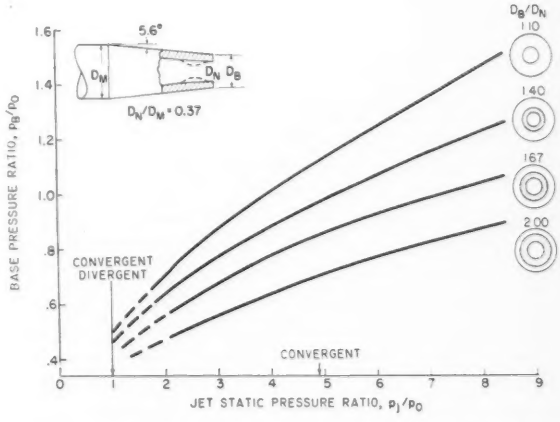


FIG. 10. Jet effects on base pressure; $M_0 = 1.9$, $\gamma_j = 1.4$.

estimated by applying the data of Drougge[7] who obtained pressure distributions in the vicinity of two-dimensional flow deflections of various angles. The method of application was as follows:

The flow deflection at the surface was calculated for a given combination of boattail angle and jet pressure ratio. From Drougge's data for the same deflection, that portion of the pressure disturbance ahead of the break in the plate was superimposed on the boattail, scaled according to the boundary-layer thickness. The resulting pressure distributions were steeper and higher than those of Fig. 7 but did not extend as far forward. This can be rationalized by the fact that the initial deflection by the jet did not persist as with the flat plates because of jet curvature; also, the boattail boundary layer was somewhat distorted toward a separation profile without the jet and was thus more susceptible to propagating disturbances upstream. It is interesting to note, however, that the drag predictions were fairly good. In view of the possible coincidental agreement, the utility of this simplified correlation must be determined by further study.

Before leaving jet interference effects on boattail pressures, several modifying factors should be considered (Fig. 9). Jet interference is reduced by anything that reduces the strength of the trailing shock at the end of the boattail. Internal expansion of the jet which reduces the overpressure (underexpansion) is one such factor. In addition, the presence of an annular base can confine the jet effects to the base pressure, unless the base pressure rises appreciably above the rearmost boattail pressures. Conversely, anything that increases the strength of the trailing shocks will increase the jet interference effect. Large boattail angles or large nozzle exit angles fall into this category. Flight Mach Number would also be expected to affect the extent of jet interference, particularly at low supersonic speeds where jet deflection of the external stream may exceed shock detachment angles and the trailing shock waves may stand well ahead of the base.

## Jet Effects on Base Pressure

When an annular blunt base is present, the peak pressure ratios of Fig. 3 may be used to estimate base pressures with sufficient accuracy to predict trends. Use of limiting pressure rises for this purpose has previously been made by Cantrell and Gazley, Love, and Cortright and Kochendorfer. One method of estimation is described herein.

The nature of this base pressure calculation is simple in principle. It is first necessary to determine the flow conditions just upstream of the base for both the external and the internal flows. This involves a calculation of flow over the boattail and within the nozzle which may be relatively simple or complex, depending on the geometries involved. A base pressure is then assumed which determines the change in direction of the two streams as they separate at the base. The paths of the jet and stream boundaries downstream of the base may then be calculated by the method of characteristics or estimated from empirical observations of jet and stream curvatures from similar flow fields. The interaction point and angle of the two streams is thus determined, and the final flow direction of the two streams is established by the requirement of equal static pressure across the dividing boundary. The average Mach Number of the jet and stream ahead of the trailing shocks (see Fig. 3) is then calculated, $\overline{M_1} = 1/2(M_{1j} + M_{1s})$. Fig. 3 is entered with $\overline{M_1}$, and, if the peak pressure ratio does not agree with that calculated across the trailing shocks, a different base pressure is assumed and the calculation repeated.

The results which can be obtained with such calculations are illustrated in Fig. 10 for a convergent nozzle in combination with a conical afterbody. For this particular calculation, the variation in Fig. 3 was neglected, and a constant peak pressure ratio of $p_2/p_1 = p_2/p_B = 2.1$ was assumed, however. As jet static pressure ratio is increased, base pressure increases. This results simply from the fact that the increased outward angularity of the jet, which accompanies increased jet static pressure ratios, increasingly deflects the external flow away from the axis and causes higher values of wake pressure $p_2$ behind the trailing shocks. Since the pressure ratio across the shocks $p_2/p_B$ must remain constant at 2.1 by assumption, the base pressure must also increase.

The effect on base pressure of base-to-nozzle-diameter ratio may be similarly physically explained. With increasing base size, the jet boundary curves increasingly toward the axial direction before it meets the external stream. Wake and base pressures thus decrease while maintaining a constant ratio.

The curves of Fig. 10 were calculated for a convergent nozzle which at the indicated Mach Number of 1.9 would have a jet-static-pressure ratio of nearly 5. Similar calculations for convergent-divergent nozzles with design jet-static-pressure ratios of 1 yield curves only slightly displaced from the indicated extrapolations of the convergent nozzle curves. It may thus be qualitatively seen that convergent-divergent nozzles will

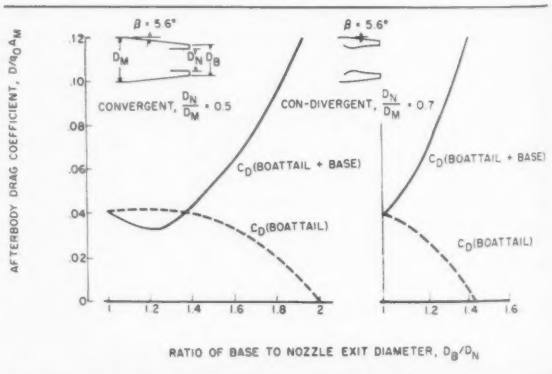


FIG. 11. Overall afterbody drag considerations; $M_0 = 1.9$, $H_1/P_0 = 10$.

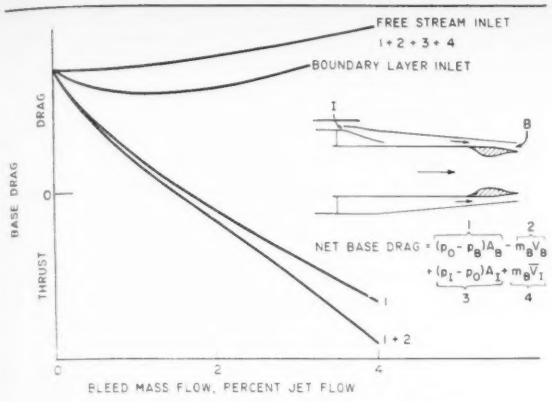


FIG. 12. Effects of base bleed; $\gamma_j = 1.4$.

generate lower base pressures than convergent nozzles with equivalent base sizes.

Peak pressure ratio concepts may in addition be used to predict the effects of boattail- and nozzle-exit-angle variations. A consistent change in either parameter will yield a family of curves similar, but displaced, to those of Fig. 10.

## Overall Drag Considerations

Some of the design implications of the interference effects which have been discussed are illustrated in Fig. 11. A convergent and a convergent-divergent nozzle serving the same engine are shown installed in a hypothetical afterbody at Mach 1.9. With no blunt bases, the calculated drags are initially the same because the favorable jet effect with the convergent nozzle nullifies the drag of that portion of the boattail removed to accommodate the divergent portion of the convergent-divergent nozzle. Thus, with no blunt base, the convergent-divergent nozzle is superior by its inherent thrust advantage at the design point. As a blunt base is added to the convergent nozzle, the drag is reduced at first. However, drag increases immediately with the convergent-divergent nozzle. Thus, at a base-to-exit-diameter ratio of 1.4, the increased drag of the latter nozzle eliminates most of its thrust advantage. This example demonstrates the type of analysis which can be made with the simplified approaches summarized herein.

## Modifying Effects of Base Bleed

Frequently the annular blunt bases surrounding nozzles are, in reality, open, and air is discharged through them. This discharge may be for the prime purpose of reducing base drag,[8] or the base may merely be a convenient place to discharge cooling or accessory air. The modifying effects of such airflow are considered only qualitatively in Fig. 12 for a typical geometry. When air is taken aboard to reduce the base drag, the net base drag may be defined as the sum of four terms. These are a base pressure term 1 and a bleed flow exit velocity term 2, the sum of which equals the total exit momentum or jet thrust of the bleed air. In addition, there are two terms 3 and 4 representing the inlet total momentum of the bleed air. With small amounts of bleed air, the base pressure and bleed air jet thrust increase rapidly. When inlet momentum is accounted for, however, a useful net base drag reduction is achieved only if the inlet air is low energy boundary-layer air. The only theoretical solution to this flow problem was advanced recently[9] but has not yet been evaluated.

## Conclusion

Some of the aerodynamic problems of achieving efficient nozzle installations for operation over a wide speed range have been reviewed. It has been demonstrated that jet-stream interactions can play an important role in these problems under some conditions. The concept of peak-pressure ratios for separated turbulent boundary layers has been found useful to describe interaction phenomena. However, the need is clear for increased research and engineering effort in this area.

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*The Flight Control System*

# Pilot, Instruments, Controls

*Will the pilot's duties ever become so thoroughly simple and orderly that he will go along just for the ride? Noting an 86 per cent reduction in power-plant controls, levers, etc., in one of today's jet vehicles, this author cites trends, developments, and concepts to place the "joy-riding pilot" well within the realm of possibility.*

## Introduction

The trend in aircraft instruments and controls is away from indicators and levers toward fully automatic flight control. Years will pass before this full transition is accomplished through the science of electronics. In the meantime, the pilot—or human link—must provide the bridge between indication and control.

The air-borne combination of pilot, controls, and instruments might best be described as the aircraft flight control system. For example, the crew receives intelligence from the aircraft's complex network of instruments and controls and without hesitation translates this information to the proper flight action.

This paper shall concern itself with the following related items of flight control: development of the flight control system, components of the system, and method of operation.

## Development of the Flight Control System

During the years between 1903 and 1950, the trend had been toward an ever-increasing number of instrument displays and control knobs to confound the aircraft crew. Since 1950, this trend has been reversed and today tends toward the growth, in both number and complexity, of aircraft control systems which incorporate the functions of many and varied instruments and controls. Figs. 1 and 2 and Table 1 indicate the growth of instrumentation and aircraft speed over the years and into the near future.

The restricted use of instruments, controls, and control systems during the period 1903 to 1919 was due mainly to low aircraft speed and altitude capabilities, combined with the bulky and not always reliable instrumentation available during that period. The early aircraft's complete flight control system consisted of the pilot, three instruments, and one control system. The instruments were engine tachometer, anemometer, and stop watch. The control system was a set of controls or levers and cables set to warp the wings. For many years these instruments and controls, plus a magnetic compass and altimeter, were the only ones used in aircraft. Later, the control systems advanced to levers that actuated, through cables, airfoil surfaces.

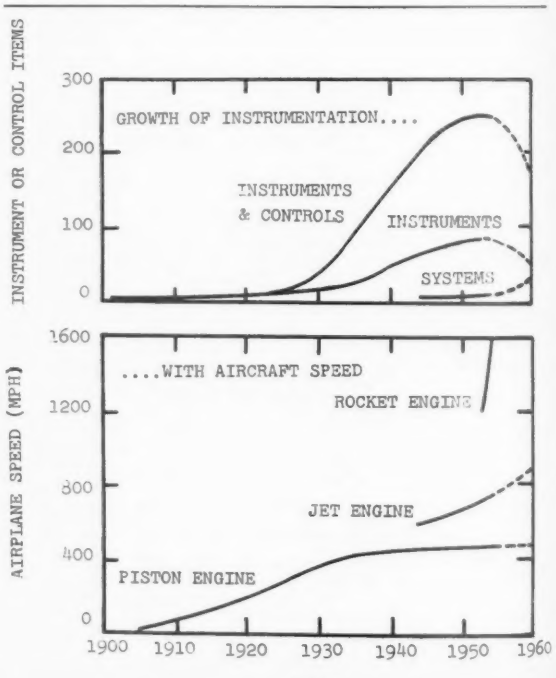


Fig. 1. Growth of instrumentation.

* Senior Propulsion Engineer.

The feasibility of scheduled transcontinental flights is dependent upon the utilization of night and foul weather flights, or so-called blind flying. To accomplish this blind flying, it was necessary to obtain workable instruments such as rate-of-climb, sensitive altimeter, and gyro-turn indicator. In 1913 Elmer Sperry successfully demonstrated the gyroscopic stabilizer, and in 1914 his automatic pilot won first prize in Paris for its outstanding performance.

With the use of some of these instruments, several astonishing records were produced. In 1913 an altitude record of 20,079 ft. and a speed record of 120.6 m.p.h. were set.

Although World War I did not add appreciably to the instrument panels in front of the crew members, it did popularize, as never before, the aircraft and its tremendous possibilities.

### *Dependence on Visual Aids Continued in the Twenties*

The decade of the Twenties saw many advances in aircraft instruments and controls, but the pilot's continued reliance on visual flight patterns—and the necessity of maintaining schedules—prompted scientists and engineers to focus their attention on bettering instruments then in use and creating the required new ones.

A most important step toward giving the pilot some means of stabilizing himself under nonvisual flight conditions was the introduction of the gyro turn-indicator. This device helped the pilot maintain altitude and flight direction and was developed as an auxiliary to the magnetic compass. Soon thereafter, the rate of climb and turn-and-bank indicators were added to the intrument panel. By 1927 flying with instruments had progressed to where it was possible to make an accurate point-to-point flight such as that accomplished by Lindbergh in his famous flight from New York to Paris. This feat acquainted both the aircraft industry and the general public with a fact that could not be denied—scheduled commercial aviation was not only feasible but an impending reality.

The decade of the Thirties was perhaps the most important in development of the airplane for commercial air lines and the start of the modern military aircraft. By 1937 air frames and engines were developed sufficiently so that the DC-3 could be produced. The first "3's" were provided with approximately 125

TABLE 1

A Tabulated Comparison of Models 377 (C97) and 707*

| | 377 | 707 | Per Cent Reduction |
|---|---|---|---|
| Power-plant controls, levers, etc. | 96 | 14 | 86 |
| Power-plant instruments and displays | 82 | 26 | 65 |
| Total controls (whole airplane) | 370 | 205 | 45 |
| Total displays (whole airplane) | 195 | 100 | 49 |

* This indicates the great reduction which can be effected by the use of jet-engine aircraft rather than the reciprocating type—and thus effect a reduction in pilot fatigue.

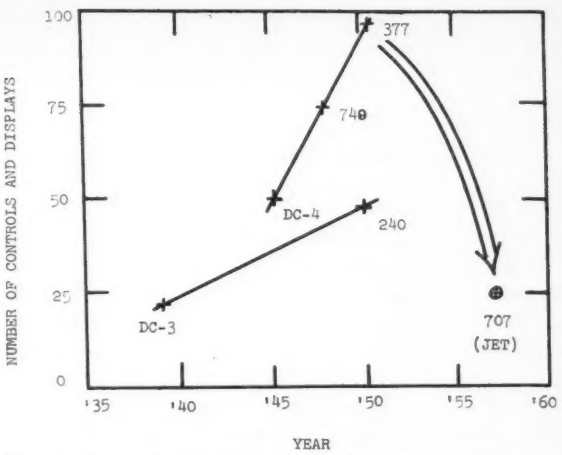


FIG. 2. Power-plant controls and displays requiring attention.

instruments and controls, exclusive of radio and navigational equipment.

### *Progress Took a 20-Year Leap in World War II*

The decade of the Forties may best be called the World War II period of development. Because of the pressures of war, the development of instruments and controls was accelerated far beyond that thought possible before 1939. It is possible that more than 20 years' progress was made in the 4-year period from 1940 to 1944. During this time, psychologists and aeromedical doctors made innumerable studies concerning fatigue, pilot error, instrument legibility, eye motions, training devices, simulators, and the like. With this tremendous store of new and scientific knowledge, the old controls and instruments were vastly improved. New concepts of instrument grouping and location were evolved. In 1946, for example, a plane could take off, fly a set course, and make an instrument landing in an emergency without application of the human hand to the controls.

A turning point in the instrument field was the synchronized gun-control system, developed by the General Electric Company and first used on the B-29 Superfortress. It paved the way for the approaching shift from a multitude of individual instruments and controls on the instrument panels and control panels toward the development of automatic and semiautomatic flight control systems. These systems use fewer panel instruments and more interrelated components located in other sections of the aircraft. Thus the great majority of the instruments and controls are out of contact with the pilot and crew, whose job is therefore lightened sufficiently to permit them to pay more attention to such things as navigation and performance of the given mission.

The development of controls revolves about two major points—reduction of the number of levers, buttons, switches, etc., and standardization of controls from one aircraft to another. For example, landing-gear and flap controls under the old methods had levers

which were dentical and often confusing. Under the new system, the gear control is shaped like a wheel, and the flap control is shaped like an airfoil section in addition to occupying given cockpit locations. As an example, the landing-gear control is always forward of the throttle; the flap control, aft. This standardized arrangement first began to appear in some of the production aircraft of 1950.

Direction of control movement is also of great importance in this standardization program. Gear and flap controls move in the same direction as the aircraft component which they control. This principle applies to all aircraft controls, such that all switches should move forward or upward for *On*, all knobs should rotate clockwise for *Increase*, and a control, such as the throttle, should move forward for *Increase*.

In the preceding it has been obvious that in all of the design developments for both instruments and controls the human factor has been the guiding light. In the beginning this was not recognized as such, and therefore equipment was not designed or located in the most efficient and sensible manner. This is indicated by the case of the altimeter. As soon as altitudes of more than a few hundred feet were reached, it was found that the human estimate of height was extremely poor. (Crash landings and the like probably served to prove this point.) This defect was, in fact, due to the ineffectiveness of stereoscopic vision beyond about 100 ft. Thus, an instrument to measure altitude was among the first required. Aircraft personnel merely took the balloon basket aneroid barometer and calibrated it in feet. This was human engineering in the raw!

### *Reaction Time an Important Consideration*

The human portion of the flight control system must be discussed in terms of human engineering as we see it today. One highly important consideration is the time needed by a trained pilot to see and react to a crisis. For example, when a pilot sights an obstacle in his path, his eye has to transmit the idea to his brain; his brain must size up the situation, decide upon correct action, then transmit the message to his hand—to grasp a control and move it in the proper way. Table 2 indicates the time involved for the average trained copilot to accomplish certain actions in handling a large bomber. Table 3 illustrates the perception-to-action time requirements under almost any aircraft speed condition.

TABLE 2
Time and Motion Study of a Bomber Copilot*

| Zone | Total Time, Sec. | Motions | Time Per Motion |
|---|---|---|---|
| Entry leg | 80 | 21 | 3.8 |
| Downwind leg | 90 | 50 | 1.8 |
| Base leg | 45 | 15 | 3.0 |
| Approach leg | 90 | 30 | 3.0 |

* A study of the motions of a copilot in a large bomber making a standard military approach and landing. The approach consisted of four zones, or legs, during which time the copilot had approximately 305 sec. to perform 116 actions.

It is necessary to be concerned with the location and shape of the controls, as discussed previously. Prior to World War II, these human engineering concepts were largely ignored, and as a consequence many accidents occurred because of the misreading of an instrument dial or the mistaken application of a control. A lack of standardization among cockpits of various aircraft has proved to be a great hazard. A pilot flying one type of aircraft for a reasonable length of time becomes accustomed to its instrument and control setup. When transferred to another type of aircraft, he finds himself automatically flipping switches incorrectly because their location is the same as a different control in the first ship. In the 22 months from January, 1943, to November, 1944, the Air Force reported that confusion between landing-gear and flap controls caused 457 accidents.

### *Lighting Without Glare an Important Advancement*

Other important items that must be attended to in the design of the overall flight control system are the visibility, seat design, cabin comfort, and instrument lighting. A good deal of work has already been done on the problem of instrument lighting. The Navy Department's Bureau of Aeronautics has developed, with instrument manufacturers, an instrument lighting system in which a light bulb is encased in the center of the cover glass, permitting dial face lighting without glare. Installation problems are reduced because of this integration of the instrument and lighting. In addition, old-type instruments in use today have been placed in a new type of back-lighted instrument panel (Fig. 3). In this geometry, which is similar in detail to the photo instrument panels used in flight-test work, the instrument is set behind a lucite or plexiglass cover in which instrument dial face holes have been cut. Lights for this panel are set into the plexiglass from the aft side. Instrument and display lighting are of particular interest to the pilot with regard to eye adjustment from "inside" to "outside" cockpit.

A typical example of the human engineering involved in obtaining the best instrument-control-pilot setup is found in the concept of an air-borne radar control panel. Rearrangement has simplified the sequence of movements and improves the possibilities for accuracy and speed. In the redesign, the original two three-position switches, located in the center, have become one five-position switch located advantageously in a corner.

TABLE 3
Perception-to-Action Tabulation Applicable to Any Craft, Any Speed

| Action | Time to Complete, Sec. |
|---|---|
| Brain perception of what eye sees | 0.1 |
| Brain recognition | 0.4 |
| Decision | 4 to 5 |
| Physical reaction | 0.5 |
| Airplane reaction (approx.) | 2+ |
| Total action time | 7 to 8 sec. |

Previously, the switches were in the way, unnecessarily accessible although never used in an emergency. For example, they were always in the movement path of the pilot reaching frequently for other controls; as a result, occasionally either or both would be inadvertently flipped. The single switch is also easier to use when the pilot wears heavy gloves.

The development of the overall flight control system is necessarily coincidental with the development of instruments, controls, and concepts of human engineering.

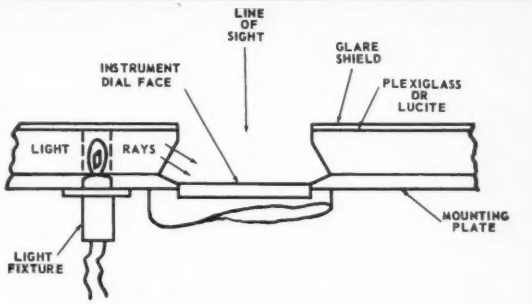


FIG. 3. Instrument panel.

## COMPONENTS OF THE FLIGHT CONTROL SYSTEM

The components of the flight control system consist of four subdivisions:

(1) The instrument devices located on instrument panels facing each crew member which, by means of dial and digital presentation, indicate many remote actions within and without the aircraft—e.g., a temperature indicator presenting, on a dial, the jet-engine tailpipe gas temperature.

(2) The control devices on or near the instrument panel and crew stations that are manually positioned so that some preselected aircraft function is performed—e.g., an engine throttle *control lever* at the pilot's station which will increase or decrease, through appropriate servos, the engine power output.

(3) The human portion of the system which will be discussed in more detail later. The pilot is mobile and is disconnected from the system at the completion of each flight. Nonetheless it is quite obvious that he is an integral part of the whole system.

(4) The partial, or individual, system which automatically combines the functions of several controls and instruments so that one lever (control device) may signal a whole series of actions. The term *instruments* as used here indicates devices that transmit intelligence within the partial system. An example of a partial system is the jet-engine control which provides acceleration proportional to the selector lever position, computes the maximum rate at which fuel can be supplied without stalling the engine, and limits the tailpipe temperature to a predetermined maximum value.

### *Other Partial Systems Listed*

Additional partial systems, which when combined form the overall flight control system, are: surface controls, navigation, ice protection, armament (guns, search equipment, bombs), power plant, landing gear, communication and emergency systems (ejection seats, etc.).

The partial systems include all the major functions that must be carried out so that the aircraft mission can be brought to a successful completion. For instance, the surface control system consists of the rudder, elevators, ailerons, flaps, aerodynamic brakes, tabs, etc., coupled with the actuating and intermediate devices required to operate them in conformance with the pilot's wishes. When the pilot pushes on his right rudder pedal, designated previously as a control, the bar linkage, hydraulic boost, pumps, cables, and such combine to move the rudder right and at the same time maintain a given feel on the rudder pedal. Instruments that are involved in the operation of this partial control system measure temperature and pressure at various locations, and these data are relayed to both the partial system and the pilot. Thus some of these instruments are actual members of the surface control partial system, which naturally includes the pilot. At the same time, various other partial systems may be in operation—and probably are.

Conventional instruments used to give quantitative and qualitative data to the pilot are generally grouped into three types: digital (direct numerical reading), those with moving pointer over a fixed scale (pointer and dial type), and those with moving scale about a fixed pointer (compass with a circular dial revolving past a hairline).

Naturally many variations occur, but these are concerned more with changes in the shape or display than with the method. Indicating instruments are useful for *quantitative reading* of an exact numerical value—e.g., fuel flow. *Qualitative reading* gives a trend or approximate variation from a given datum—e.g., gyro-turn and bank. *Check reading* verifies that a desired value is being indicated—e.g., using magnetic compass to check gyro compass. *Setting* to a desired value establishes a zero point or limit value—e.g., air speed, altimeters, etc. *Track ng* is intermittent or continuous adjustment of an instrument to maintain a desired value regardless of instrument indicated change or to follow a moving reference such as compass direction indicator. Table 4 indicates the relative value of each instrument type with respect to the uses to which it can be put.

### *Industry Leans Toward Master Warning Light*

Warning lights are considered a part of the instrument panel since they are indicators requiring, in most cases, some kind of pilot action. At the present time, industry is leaning toward a master warning light which will refer the pilot to a lighted panel. This panel will indicate, in a direct form, the source of trouble.

A partial list of the many items that fall in the controls category includes throttle levers, flap controls, radio knobs and switches, stick or wheel, rudder pedals,

TABLE 4
Table of Recommended Indicators According to Use

| Method of Use | Moving Pointer | Moving Scale | Counter |
|---|---|---|---|
| Quantitative reading | Fair | Fair | Good<br>Minimum time and error in obtaining exact numerical value |
| Qualitative and check reading | Good<br>Location of pointer easily detected; numbers and scale need not be read; change in position easily detected | Poor<br>Difficult to judge direction and magnitude of the deviation without reading numbers and scale | Poor<br>Must read numbers; no easily detected position changes |
| Setting | Good<br>Simple and direct relation of pointer motion to motion of setting knob; aids in monitoring | Fair<br>Somewhat ambiguous relation to motion of setting knob; no pointer position change to aid in the monitoring; not readable during a rapid setting | Good<br>Most accurate monitoring of numerical setting; relation to motion of setting knob less direct; not readable during rapid setting |
| Tracking | Good<br>Pointer position readily monitored | Fair<br>No pointer position changes to aid in monitoring | Poor<br>No gross position changes to aid monitoring |

etc. In all of these cases, it can be seen that something must be mechanically positioned to produce some action through the previously mentioned partial systems. These cockpit controls exhibit three important design characteristics—geometrical design, location, and method of action. Each lever, knob, stick, and button should be designed for its own specific position and action to perm t efficient, rapid operation of the controls.

The human portion of the flight control system is an integral part of this complex servo setup. There was a time when the pilot's main mission was to keep the aircraft in the air and to get it back safely on the ground. Today's military and commercial pilots and crew members spend many hours on initial and refresher instrument flight training. This is an untenable situation in the military supersonic flight age almost upon us. Difficult as it may be to comprehend, we now realize that the pilot of the supersonic age can be provided with only a comparatively few hours of actual instrument and control training. Most of the military pilot's time will be spent in military tactics training so that he will react promptly and properly when, in actual combat, a decision is required. The answer to this complex problem can be supplied only by the combined efforts of instrument and control engineers, aviators themselves, human engineers, and aeromedical personnel. Thus we see that the pilot's capabilities, regardless of how good, must be supplemented by many devices and concepts of flight control.

## Coordinated Operation of the Flight Control System Components

The coordinated operation of the components that make up the flight control system is the end result of the design and development programs discussed previously. Their operation has been shown, to a great degree, in the previous pages.

The flight control system coordination might best be shown by a theoretical example: The aircraft is initally in straight and level flight under cruise conditions. The pilot perceiving a target above and forward of this position decides to close with it. Of the partial systems in the aircraft, only the following are utilized: surface controls, power plant, armament, and compartment conditioning (which is in automatic operation for most of the flight).

Thus, these four partial control systems form the complete flight control system for this particular combat maneuver. The pilot, upon receiving the visual signal of a target, makes a decision on a course of action and begins the new maneuver. The throttle lever or control is pushed forward to maximum power setting. The stick and rudder pedals are put into action, the armament readied. These motions complete, the flight control system carries out the action to maintain the aircraft and equipment in the proper attitude required to fulfill the mission. A similar process is carried out in the pull-out and recovery so that the aircraft is in the correct spacial location with respect to the target.

Taking any one of the above controls, except those operating automatically, we can resolve the pilot and system action as follows:

(1) Stimuli—visual, audible, feel.

(2) Pilot reaction to stimuli—push or pull lever (control), turn knob, etc.

(3) System action—the pilot's reaction in positioning a control sets a system in action leading to the final desired control movement.

(4) Along with (3) above—modification of system action by instrument inputs to the subject system.

(5) Aircraft action—response to all of the above.

(6) New instrument readings on the instrument panel with inherent new stimuli. Thereupon action (1) begins again.

## Conclusions

In the future, as the speed and altitude of flight moves upward, there will be a greater consolidation of instruments and more use of flight control systems in place of individual instruments and controls. The pilot's cockpit is becoming simpler, more orderly, and

to some extent standardized so that one day the pilot may go along just for the ride.

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[3] *Operation Standard*, Flying Safety Magazine, July, 1954.

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## Economics of Rocket-Propelled Airplanes

(*Continued from page 36*)

(b) *Results:*

(1) Oil and liquid oxygen (mixture ratio—2.75); cost of oil—12 cents/gal. (= 2 cents/lb.); cost of liquid oxygen—$10/ton (= 0.5 cent/lb.). Cost of propellant mixture is 0.887 cent/lb.

(2) Liquid hydrogen and liquid oxygen (mixture ratio—4.0); cost of hydrogen—8 cents/lb.; cost of oxygen—$10/ton. Cost of propellant mixture—2 cents/lb.

(3) Liquid hydrogen and liquid oxygen (mixture ratio—9.0); cost of hydrogen—8 cents/lb.; cost of oxygen—$10/ton. Cost of propellant mixture—1.25 cents/lb.

(4) *Results*—Propellant costs are given in Table 4-3.

***(C) Interest on Investment: Taxes, Insurance***

(1) *Interest*—The air-line operator must pay interest on the capital invested in airplanes and other capital equipment. It will be assumed that the interest rate on borrowed capital is 6 per cent per year.

Contemporary transport airplanes cost about $25/lb. of empty weight, fully equipped. A figure of $60/lb. of empty weight has been used throughout this study. The higher figure was used for several reasons:

(a) Rocket airplanes will be made from more expensive materials and will be harder to fabricate than contemporary airplanes.

(b) The cost per pound of airplane is increasing with time.

(c) The charges attributable to structural costs are relatively small in most cases considered. Consequently, one can easily afford to be conservative and to make generous allowances for costs of the rocket airplane structure.

Assume, as is common, that the rocket airplane flies 3,000 hours each year. The operator then pays for each pound of airplane structure

$$\frac{6{,}000 \text{ cents} \times 6\%}{3{,}000 \text{ hours}} = 0.12 \text{ cent/hour of flight}$$

(2) *Taxes and Insurance*—Taxes are a variable and controversial factor. Insurance against loss of airplane usually costs somewhat less than interest. Taxes and insurance have been lumped and assumed to cost 0.10 cent/lb. of structure/hour of flight in the computations which follow. [See (H), "Direct Flying Costs."]

*The concluding Part II of Mr. Cornog's paper in the October issue will resume discussion of "Direct Flying Cost of Rocket Airplanes" and take up current freight rates, passenger fares, and projected costs of air transportation. Three appendixes and the author's conclusions will also appear*—ED.

## IAS News

(*Continued from page 27*)

five stops for fuel, the company claims. A full-scale mock-up of the 707 Stratoliner cabin has been placed on display in New York. The mock-up has 98 seats, two galleys, and four lavatories, complete with lights, running water, and air conditioning. Boeing has issued a brochure on the 707 airplane and another booklet showing how the 707 air liners will fit into airport and terminal operations.

• **Bristol Aero-Engines Limited** announces that the British Government has given approval for the sale of civil versions of the Olympus turbojet engine to aircraft manufacturers and air-line operators. The military version of the Olympus, now in production, is rated at 12,000 lbs. thrust.

• **Douglas Aircraft Company, Inc....** Closed circuit television is being used at the Santa Monica plant to save the time of engineers who formerly used to be called out to the factory area, 4,000 ft. from their offices, to check on the accuracy of machined parts. Now the part in question is placed under the TV camera in the production area, and the image is transmitted to a 21-in. screen in the engineering department. Armed with blueprints and the original analysis, the design and strength engineers look at the magnified picture and usually can make a final determination without walking out to the factory. . . . Douglas Aircraft Company has announced it will give scholarships, fellowships, and other educational grants totaling more than $130,000 during the coming school year. About $95,000 of this financial aid is available to company employees. In addition, sons and daughters of employees are eligible for 130 college scholarships of $100 each.

• **Elastic Stop Nut Corporation of America** has introduced a new one-lug cap seal anchor locknut designed for integral aircraft fuel tanks in which space for riveting is limited or where bolt holes are close together. The No. A2507 self-sealing locknut prevents leakage up to 50 psi on either side of the seal, despite severe vibration or temperature changes.

• **Ethyl Corporation...** Edward L. Shea, President since 1947, has been elected Chairman of the Board. B. Bynum Turner, formerly Executive Vice-President, has been elected President.

• **Fairchild Camera and Instrument Corporation...** In addition to rewarding inventiveness with better jobs and better salaries, the company has adopted a policy of "increased recognition" to encourage its engineers in product research and development. At the end of 1956, a plaque will be awarded for "the best patent of the year" at a banquet to be held by the company for all technically trained engineering personnel. The plaque will be accompanied by a personal gift. The banquet is to be an annual affair. All patent applications will specify the engineer's name and will be given maximum publicity through the employee newspaper and through circulation of copies to top company officials and to all engineering personnel. Certificates suitable for framing and visits to the inventor's work place by top company officials, including the Board Chairman, are other facets in the program of increased recognition. In addition, if the company decides not to act on a patent, title will revert to the initiator. Sherman M. Fairchild, FIAS, who holds 24 patents himself, founded the company in 1920 for the purpose of marketing an invention of his own—the first automatic aerial camera. . . . Richard Hodgson, Executive Vice-President, and Joseph Bradford Wharton, Jr., of Baltimore, have been elected to the Board of Directors.

• **Fairchild Engine and Airplane Corp.** ...An addition with 11,400 sq.ft. of floor space is being constructed at the Stratos Division plant in Bay Shore, Long Island, N.Y.

• **The Garrett Corporation...** The AiResearch MA-1A trailer unit, a ground auxiliary power cart, has passed qualification tests and has been accepted by the Air Force. The trailer contains a small gas turbine engine which provides compressed air for starting jet-aircraft engines and for other pneumatically operated equipment. The unit operates at temperatures ranging from 130°F. to −65°F. . . . The AiResearch Aviation Service Division is offering a "Maximizer Kit" for DC-3's. Installed at a cost of $15,000, it is said to add about 20 m.p.h. to the plane's speed. The modification consists of an integrated system of engine cowling, engine baffles, oil-cooler ducting, wheel-well doors, and exhaust system. ...The Airsupply Company has opened a branch office at 3311 South Broadway, Englewood, Colo.

• **General Dynamics Corporation...** Convair Division is building a $40,000,000 plant, to be known as Convair-Astronautics, at Montgomery Field near San Diego Calif. It will be devoted to research, development, manufacturing, and preliminary testing of the Atlas intercontinental ballistic missile. Situated on a 252-acre site, the plant will consist of a one-story factory building of 500,000 sq.ft., two six-story office buildings with 107,000 sq.ft. each, an engineering laboratory with 147,400 sq.ft., an instrument and computer center, a cafeteria-auditorium, and several test and utility buildings. The plant will be completed next year and will employ 6,600 persons by 1958. . . . Convair has announced it will build a medium-range jet transport with a cruising speed of 609 m.p.h. at its San Diego (Calif.) plant. Called the Golden Arrow, the new commercial air liner will have a golden exterior instead of the usual silvery color. It will cruise at 35,000 ft. with a pressurized cabin and will operate efficiently at ranges from 200 to 3,000 miles, the company said. It will operate from 5,000-ft. runways. It will be powered by four General Electric CJ805 engines. The first Golden Arrows will be delivered to Trans World Airlines, Inc., late in 1959. Delta Air Lines, Inc., also will use the plane. . . . Convair has built a new rocket sled that travels 1,560 m.p.h. on the 10,000-ft. track at the ARDC's Flight Test Center at Edwards AFB, Calif. Speeds in excess of Mach 2 have been reached on a regular schedule during rain-erosion tests. The sled races through a simulated rain storm carrying an exposed part of an aircraft or missile on its nose. At the end of the run, the sled is recovered with no damage from deceleration, and the effect of rain on the test specimen is evaluated. The sled weighs only 800 lbs. The sled has seven rocket bottles, and a pusher sled (booster) has five more. In previous rain-erosion tests, material samples were fired from a 20-mm. gun, but the specimens were necessarily small.

• **General Electric Company...** The Small Aircraft Engine Department has developed a "welterweight" gas turbine engine, the T58, for the Navy's Bureau of Aeronautics. It was designed specifically for helicopters and will be flight-tested in the Sikorsky S-58. The T58 engine has a continuous output of 900 hp. and a military rating of 1,050 hp. It weighs 250 lbs. (325 lbs. including gearing) and is

**Close-up view of Convair's Mach 2 rocket sled shows the metal test specimen mounted on the nose for a rain-erosion test. The 800-lb. sled, much lighter than other sleds used on the same track, runs on four steel slippers that get red hot during the 9[illegible]-sec. race. The seven rockets are ignited electrically after the sled has been accelerated to 620 m.p.h. by a pusher sled.**

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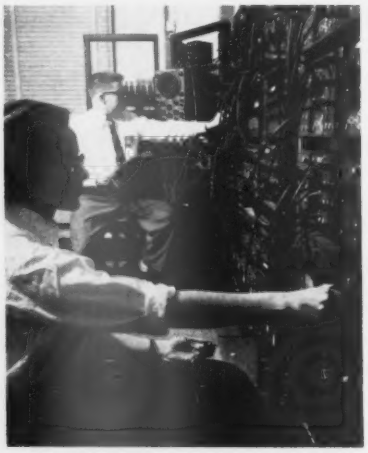
54 in. long. The T58's power-to-weight ratio is better than 3 to 1—an improvement over piston engines used to power helicopters, which average 1 hp. per lb. of engine weight. The company claims that, in antisubmarine warfare where endurance is an important factor, a helicopter powered by a T58 turbine engine could stay aloft 50 per cent longer than a helicopter with an equivalent piston engine. A cargo helicopter could double its ton-mile capacity with the turbine engine. . . .C. W. LaPierre, MIAS, Executive Vice-President in charge of the Electronic, Atomic, and Defense Systems Group, has announced a reorganization of the company's 16 electronics businesses and five electronics laboratories into three new divisions. George L. Haller, AFIAS, formerly General Manager of the Laboratories Department, has been named General Manager of the Defense Electronics Division, located in Syrcause, N.Y. The other new divisions are the Industrial Electronics Division in New York, and the Electronic Components Division in Owensboro, Ky. ...G-E will sponsor a conference on jet-engine overhaul problems at its Evendale (Ohio) plant on October 10–12. Papers will be presented by engineering maintenance representatives of the Air Force, Navy, Army, and commercial air lines, as well as by G-E engineers. This will be one of the first assemblies of both military and industry maintenance personnel for the discussion of overhaul problems connected with jet engines.

• **G. M. Giannini & Co., Inc. . . .** A high-temperature precision potentiometer rated to 200°C. has been developed by the Electromechanical Division. The new Model 875T is a servomount, subminiature, single-turn, rotary unit with a power rating of 2 watts at 150°C. Despite its small diameter of 7/8 in., linearity is plus or minus 0.5 per cent or better, and resolution is as high as 0.06 per cent. Precious metals are utilized in the coil and wiper to permit low contact pressure and to provide long, noise-free life.

• **The B. F. Goodrich Company...** J. W. Keener and Arthur Kelly, both Vice-Presidents, have been elevated to Executive Vice-Presidents. Joseph A. Hoban has been elected Vice-President—Marketing. E. F. Tomlinson has been elected President of the B. F. Goodrich Tire Company, a Division of The B. F. Goodrich Company.

• **Goodyear Aircraft Corporation** has developed two thrust-reverser units for jet engines as a result of investigations started in 1953 for the Power Plant Laboratory of Wright Air Development Center. In one design, a deflector reroutes all mass flow normally passing through the tailpipe, turning it in a forward direction. In a second design, a partial block is achieved by projecting a deflecting mechanism into the normal gas path to divert whatever concentration of mass flow is desired into the inlets of reverser cascades. It is possible to produce the required reverse thrust without affecting the normal rated forward thrust of the engine, according to company engineers.

• **Harvey Aluminum Division of Harvey Machine Co., Inc....** New offices have been opened at 1430 Peachtree St., N.W., Atlanta, Ga., and 505 Park Ave., Detroit, Mich.



**General Electric Co. uses this computer in its Lynn (Mass.) plant to simulate engine control and aircraft characteristics. It is employed in "test flying" small gas-turbine engines such as the T58 and the MX2273.**

• **Lear, Incorporated...** The Lockheed F-104A jet interceptor will use Lear's new three-axis stability augmenter, an electronic device that enables a plane in flight to damp out automatically any deviations from the desired flight path. This is believed to be the first transistorized flight-control device put into production for supersonic aircraft. ...The first automatically controlled flights by an American jet transport, according to Lear, have been made by the Boeing 707 prototype to test the MC-1 electronic autopilot, which will be installed in Boeing's KC-135 tanker-transports ordered by the Air Force. A similar Lear autopilot has been flying for several months in the French Caravelle jet transport....The Grand Rapids Division is building a manufacturing plant with 170,000 sq.ft. of floor space at the Grand Rapids (Mich.) Airport....Edward Adams, Jr., a Vice-President of the National Bank of Detroit, has been elected to Lear's Board of Directors. ...A 15-min. color film on the Civil Air Patrol, sponsored by Lear Incorporated, will have its first showing this fall in Washington, D.C. Among the actors will be William P. Lear, AFIAS, who is an adviser to the national commander of the CAP.

• **Lockheed Aircraft Corporation...** A new jet airplane capable of "routine flights" at a height of 10 miles has been developed by Lockheed for the Air Force. Known as the U-2, it has a large wing to provide extra life in thin air and is powered by a Pratt & Whitney J57 turbojet engine. It can stay at 50,000 ft. an hour or more. The U-2 was built by Lockheed with its own funds for testing engines, fuel systems, and materials in continuous flight at high altitudes. It was designed to gather information that no altitude pressure chamber can furnish satisfactorily. It carries a heavy load of instruments. Several of the fast new planes, loaned by the USAF, are being used by the NACA to gather information on clear-air turbulence, convective clouds, wind shear, and the jet stream at high altitudes up to 50,000 ft. With support from the USAF Air Weather Service, this NACA program is expected to furnish data for laying out tomorrow's high-altitude air routes for jet air liners. The first flights are being made in the Rocky Mountain area. Availability of the U-2 makes it possible to gather the high-altitude data needed "in an economical and expeditious manner," the NACA said. At the request of the Air Force, the NACA research flights with the U-2 also will be used to obtain information on cosmic rays and the concentration of ozone and water vapor in the atmosphere at high altitudes....Two large electronic computers have been installed in the Georgia Division's plant at Marietta, and a third computer is on order....The Georgia Division has opened an aeronautical engineering office in Dunedin, Fla., on the Gulf coast. About 35 engineers are employed there.

• **Manning, Maxwell & Moore, Inc.,** of Stratford, Conn., has issued a bulletin on its American bimetal dial thermometers.

• **Marquardt Aircraft Company . . .** The Research Division has moved into the first unit of what eventually will be the Marquardt Research Center. This will include a research headquarters building, an experimental and model shop, a materials and process laboratory, and a research testing facility. John Drake, MIAS, is Director of Research.

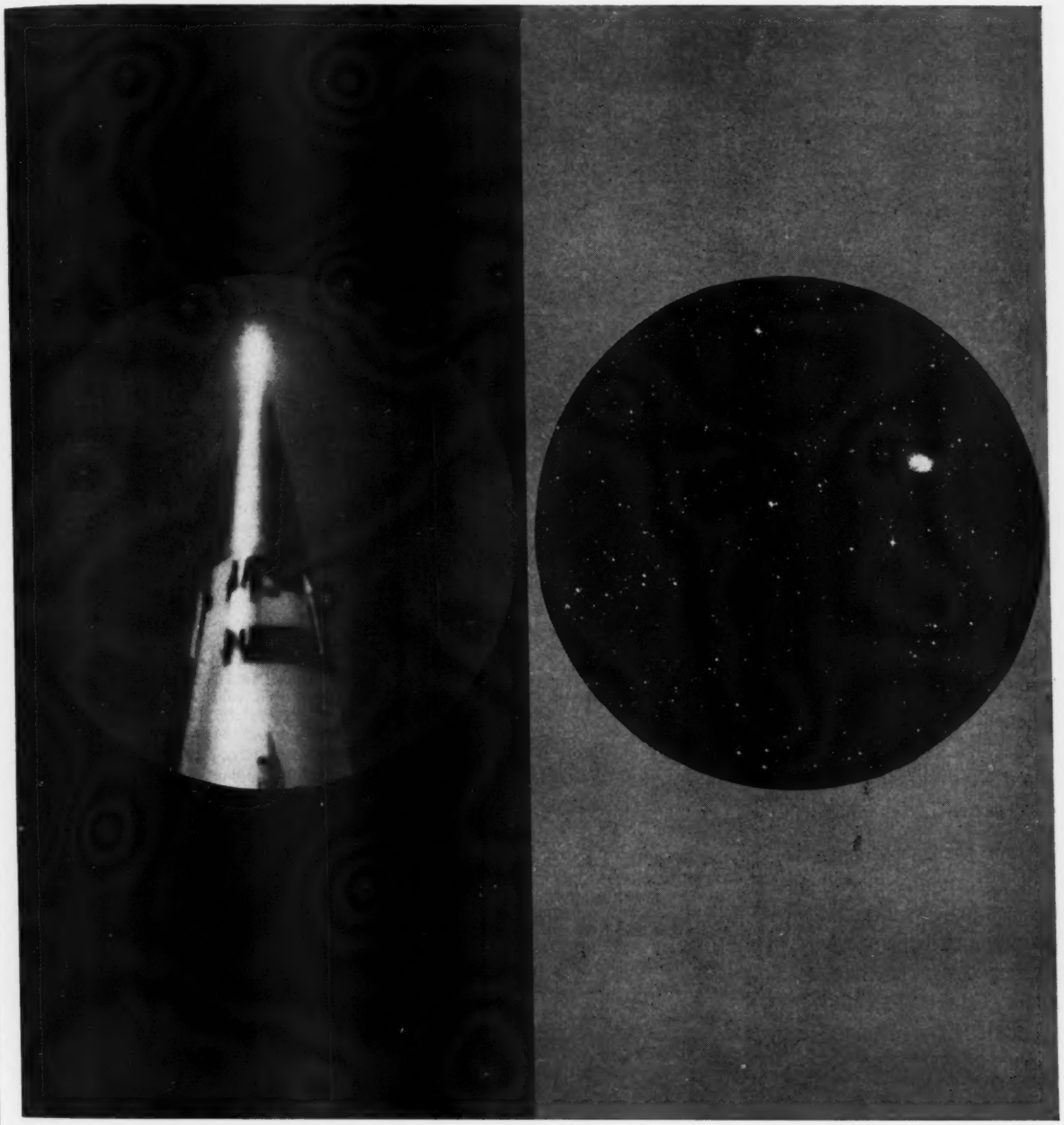
• **McDonnell Aircraft Corporation...** The F-101B is expected to fly early next year. This is the two-man interceptor version of the Voodoo which will be used for continental defense by the Air Defense Command of the Air Force.

• **Minneapolis-Honeywell Regulator Co. ...** Glenn E. Seidel has been promoted to Vice-President in charge of Engineering. He joined the company in 1943 as a field engineer and became a Vice-President in 1952.

• **Norden-Ketay Corporation** announces new analog-to-digital converters in a complete range of counts up to 524,288. It is estimated that these units will operate for 4,000,000 revolutions (better than 500,000,000 counts at 200 r.p.m.) before cleaning is required. Bulletin No. 372 may be obtained from the company's New York office.

• **North American Aviation, Inc....** After first announcing that Aerojet-General Corporation would operate a $13,000,000 Government-owned plant now under construction in Neosho, Mo., the USAF Air Materiel Command appointed the Rocketdyne Division of North American Aviation to manufacture large liquid-propellant rocket engines there. About 1,000 persons will be employed in the plant by early 1957. Active in missile programs for the past 10 years, Rocketdyne has its main plant in Canoga Park, Calif.

• **Northrop Aircraft, Inc....** A subsonic wind tunnel designed to operate at speeds up to 285 m.p.h. (Mach 0.37) has been erected at the Northrop plant in Hawthorne, Calif. The test section is 7 by 10 ft....A new Ground Support and Test Equipment Department has been established to coordinate production of nearly 300 items, from test fixtures to launching



## HOT TIP

One day not many months from now a Martin rocket—carrying the first man-made earth satellite—will depart this world at an unheard-of speed of 18,000 miles per hour...destination, outer space.

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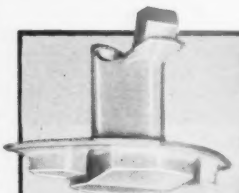
**FREEDOM OF DESIGN**

This magnesium rudder component on a jet bomber consists of two hollow rectangular chambers joined by a tube. A wall thickness of 0.08" is uniformly maintained, proving that extensive areas of thin section and complex curvature can be investment cast without resort to joining.



**FREEDOM OF ALLOY SELECTION**

In order to increase the strength and creep resistance of this jet engine strut, the material specification was changed from stainless steel to a special low alloy steel. Investment casting offers this freedom in choice of alloy at little or no extra cost.

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*"PIONEERS IN INVESTMENT CASTING"*

platforms, required for handling the Snark SM-62 intercontinental guided missile....Northrop Aircraft has established a work-study fellowship program with the University of California at Los Angeles. The company will give cash awards and part-time employment to eligible undergraduate and graduate students of UCLA while they continue their engineering education. The plan also permits students to work and go to school in alternate semesters. Students aided by the company will be offered full-time employment when they complete their studies.... Northrop has produced a 16 mm. motion picture, with color and sound, entitled *Airman Smith, Candidate for Honors.* Filmed at two Air Force bases in California, it shows the F-89D Scorpion in action and the interesting life of a technician who helps keep the planes flying.

• **Pan American World Airways** has leased from the Port of New York Authority a 17-acre site for construction of a passenger terminal at New York International Airport (Idlewild). The lease runs for 27 years. The building will be completed next summer. A new headquarters and maintenance base for Pan American's Atlantic Division is under construction at Idlewild on a 76-acre site. It will have air-conditioned offices and shops and a huge hangar capable of accommodating ten of the largest air liners. There will be parking space for 23 additional airplanes....Pan American World Airways has been selected by the United States Olympic Committee to fly more than 350 American athletes, trainers, and officials to the Olympic games in Melbourne, Australia, in November.

• **Pesco Products Division, Borg-Warner Corporation,** has opened offices in Los Angeles, Seattle, and Wichita, Kan., to handle sales of its fuel pumps, hydraulic pumps, and other products.

• **J. B. Rea Company...**The Data Storage Devices Division announces a new line of multiple-channel magnetic recording and playback heads for a variety of uses, including computer input-output equipment, memory drums, discs, and telemeter recording. The audio field also is covered with heads for 1/4-in. tape, 16-mm. film and 35-mm. film. Unique design and construction methods, the company claims, have eliminated all the major disadvantages previously existing in magnetic heads.

• **Republic Aviation Corporation...**The Guided Missiles Division has moved its main engineering and administrative offices from Hicksville, Long Island, N.Y., to a two-story building in nearby Mineola. Robert G. Melrose, MIAS, General Manager of the Guided Missiles Division, said that his engineering staff will be greatly expanded. Two current projects are the development of an air-to-air missile system and of a fire-control system for directing an air-borne missile toward a target on sea or land....The Guided Missiles Division is producing for the Navy a low-cost bombing training device called the "practice bomb dispenser." Shaped like an external fuel tank, it is packed with electronic equipment and carries practice bombs which are released through bomb

bay doors. The entire device can be shackled to any one of a number of operational Navy fighter-bombers, which makes it highly practical for field use. The bombing trainer carries four small practice bombs which weigh only 56 lbs. each and cost only $20 each. The electronic equipment registers the simulated bomb drop on the pilot's cockpit instruments. Republic is developing a similar unit for the Air Force.

• **Ryan Aeronautical Company** reports one of its Firebee jet target drones made a record flight of 105 miles from its remote-control station at the Naval Air Missile Test Center, Point Mugu, Calif. Controlled by radio from the beach, the missile flew 105 miles to sea at an altitude of 20,000 ft. and a speed of 300 m.p.h. and then was turned back and retraced its route for a total run of 210 miles. A jet plane escorted the Firebee, which had been launched in the air from a Navy JD-1 plane. A short distance from shore, the Firebee's automatic parachute was released, and the target was recovered by a Navy boat. It was the tenth mission for this particular "bird."

• **Sperry Gyroscope Company Division of Sperry Rand Corporation**...The first SP-30 electronic flight-control system, a prototype, will be delivered to Douglas Aircraft Company, Inc., this fall. It was designed for the Douglas DC-8 jet air liner and eventually will be installed in 114 DC-8's ordered by 11 air lines. The lightweight, transistorized SP-30 system will permit "hands off" control at all cruising speeds and altitudes.

• **Weber Aircraft Corporation** has licensed R. E. Atckison, of Los Angeles, to manufacture and sell Weber Aeroramps. Made in two sizes, the Aeroramp is a movable passenger stairway for air liners.

• **Westinghouse Electric Corporation** plans to build a four-story wing on its new Research Laboratories at Churchill Borough, Pa., near Pittsburgh. The wing of 150,000 sq.ft. will house the Materials Engineering Department, which finds practical applications for new and improved materials.

# IAS SECTIONS

## Hagerstown Section

Claude S. Huber has been elected Chairman of the Hagerstown Section. The other new officers are J. A. Neilson, Vice-Chairman; R. W. Bradham, Secretary; and E. F. Kuklewicz, Treasurer.

Members of the new Advisory Committee are Louis Fahnestock, E. R. Gelvin, Phil Harr, T. W. Sisson, and G. W. Westphal. The Representative to the Nominating Committee for Area Councilors is R. A. Darby.

There were 250 members and guests at the June 19 meeting. Program Chairman W. H. Arata, Jr., introduced the speakers, who made up a forum representing and discussing the various divisions of Fairchild Engine and Airplane Corporation.

Louis Fahnestock, Director of Projects Administration, discussed the Aircraft Division; Charles W. Fass, Jr., Customer Relations Manager, the Stratos Division; A. W. Doherty, Contracts and Service Manager, the Guided Missiles Division; Norman E. Briggs, Assistant Manager, Gas Turbine Division, the Engine Division; and Paul J. Frizzell, Vice-President, Fairchild Engine and Airplane Corporation, the Kinetics, Speed Control, and Electrotechnics Divisions and the Fokker Aircraft, Transair System and Armalite Groups.

The purpose of this forum was to discuss current and planned programs of each division of Fairchild Engine and Airplane Corporation. Each speaker related the activities of his particular division. At the conclusion of each brief talk, the forum was open for general discussion.

C. L. CHUMLEY
*Secretary-Treasurer*

## Hampton Roads Section

The Hampton Roads Section climaxed an eventful year of activities with a dinner dance held at the Williamsburg Lodge on June 30. Sixty-seven members and guests of the section attended the affair.

The results of the election of new officers were announced by Chairman Albert L. Braslow. These newly-elected officers are: Chairman, Richard E. Kuhn; Vice-Chairman, Lewis R. Fisher; Corresponding Secretary, Paul A. Hunter; Recording Secretary, Richard T. Whitcomb; and Treasurer, Axel T. Mattson. The Advisory Board is composed of Jean A. Roché, Melvin N. Gough, Charles H. Zimmerman, Hartley A. Soulé, Samuel Katzoff, Emanuel Boxer, and Albert L. Braslow.

The speaker for the meeting was Melvin N. Gough, a Fellow of the Institute and Chief of the Flight Research Division of the NACA Langley Aeronautical Laboratory. Aside from being a speaker of note, Mr. Gough has a background of many years of flight-test and flight-operations experience.

Mr. Gough introduced his talk by indicating that, in keeping with the aims and objectives of the IAS to "advance the arts and sciences of aeronautics by any and every act," he was dedicating his remarks to the ladies. Describing briefly the place which aviation has earned in the field of transportation, Mr. Gough pointed out that a great selling job still remains to be done and that the aviation horizon is unlimited. The future and the very survival of mankind depend upon creative imagination—a field in which, in every walk of life, women have proved more capable than men. In the comparatively new and rapidly growing field of human engineering, women have become indispensable.

In concluding his "Aviation Message to the Ladies," Mr. Gough emphasized the contributions of aviation to a better future by reference to the article by Kurtz entitled "Towards Tomorrow." Throughout the talk, humorous analogies favorable to the ladies were made to broaden their understanding and that of the scientists to whom these ladies were socially dedicated. This cause is, after all, applied imagination.

The speaker was introduced by Lawrence K. Loftin, Jr., Program Chairman.

LEWIS R. FISHER
*Recording Secretary*

## Seattle Section

The June 30 meeting was held at the Nike missile site at Midway. The missile site, occupying 50 acres, is divided into two areas—control and launching. Tours were conducted through both areas. The tours ended with a drill demonstrating the action taken when an alert is sounded upon the approach of enemy aircraft.

ELAINE GETHING, *Secretary*

## Washington Section

Thomas L. K. Smull, of the NACA, has been elected Chairman of the Washington Section for 1956–1957.

The other new officers are: Vice-Chairman, Capt. Alfred B. Metsger, of the Navy Bureau of Aeronautics; Secretary, George T. Hayes, of Stanford Research Institute; and Treasurer, Gerald L. Desmond, of the Bureau of Aeronautics.

Members of the Advisory Board are A. Wiley Sherwood, of the University of Maryland faculty; Abraham Hyatt, of the Bureau of Aeronautics; Capt. S. S. Sherby, USN; and S. Scott Hall, of the British Ministry of Supply Joint Services Mission.

**Attention Members!**

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review.*

# STUDENT BRANCHES

## The Aeronautical University

The Student Branch sponsored a field trip with SAE student members to the plant of the Standard Oil Company, Whiting, Ind., on June 12. Knute C. Hansen, an Aeronautical Engineering Instructor, acted as Faculty Adviser for the trip.

William Obermiller, of Standard Oil Company, conducted the group through the Whiting Refinery area of 1,660 acres. Observations were made of crude distillation, sweetening operations, catalytic and thermal cracking, lube oil treating, phenol extraction, propane dewaxing, and motor-oil blending units. Along the tour Mr. Obermiller described the process by which these units change crude oil into products that serve the people.

After lunch in the administration building, the group was conducted through the engineering building and research laboratory by the laboratory staff.

Research in refining processes of high-octane gasoline for aircraft engines was shown by Sam Young, Standard Oil chemical engineer, who explained the various oil tests on engines. Mr. Young conducted a tour of the engine laboratory.

Chairman Clarence Gorski was in charge of arrangements for the field trip. James Kilar, Chairman of the SAE Student Branch, provided the transportation.

The following officers have been elected for the coming school year: Chairman, Clarence P. Gorski; Vice-Chairman, Jesse C. Fugate; Secretary, Scott F. Hoo; Treasurer, Arnold E. Pryhuber; and Faculty Adviser, Alfred Stott.

Thirty student members of the SAE attended a joint meeting with the IAS on May 29, when plans were discussed for the visit to the Standard Oil refinery.

SCOTT F. HOO, *Secretary*

## Alabama Polytechnic Institute

New students were invited to the first meeting of the summer quarter on June 26. Officers of the Student Branch explained the advantages of IAS membership.

Ray Sanders, of the Aeronautical Engineering faculty, spoke on "Aerial Application in Agriculture."

The following officers have been elected for the summer and fall quarters: Chairman, Don Spring; Vice-Chairman, Wayne Patterson; Recording Secretary, John Barnes; and Corresponding Secretary, Charles Holleman.

The following Committee Chairmen have been appointed: Publicity, Irwin Strickland; Projects, Gerald Mosely; Meetings and Papers, Wayne Patterson; and Attendance, John Barnes.

New members of the Student Branch are Franklin M. Keller, James O. Romine, and Kelton C. Bruce.

JOHN A. BARNES
*Recording Secretary*

## Boston University

What should you expect when you graduate? To gain some insight into this oft-posed question, Jean Duvivier, a 1955 graduate of Boston University's College of Industrial Technology, was asked to present "A Brief Outline of One Graduate's Experience" at the April 16 meeting. Mr. Duvivier is employed in the Aeroelasticity Laboratory at M.I.T. His work has to do with stress problems arising from heat.

When he started work, Mr. Duvivier's feeling was one of bafflement. His first 4 or 5 months were consumed in poring through texts and other printed material in an attempt to gather the necessary information with which to start work on the problems he had been given. This process seems to be universal for the recent college graduate. He felt that the most important piece of advice he could offer to undergraduates was that they should acquire as thorough and extensive a mathematical background as possible. Much training and research is needed to become efficient, proficient, and useful in any job, and a good background in applied mathematics is a prerequisite to the accomplishment of these objectives.

Specifically, Mr. Duvivier's present work has to do mostly with the effect of heat on helicopter blades. The strength of the component material decreases as it becomes hotter. As the thermal capacity is reached, the metal fails. The total problem is composed of three subproblems which concern the three types of heat transfer: (1) radiation, or heat transfer from body to body; in particular, energy transmitted from the sun to a body; (2) convection, the transference of heat by moving masses of matter; and (3) conduction, the transmission through or by means of a conductor—i.e., internally. There are a number of methods that may be used to solve the total problem, among which are pure mathematical solution,

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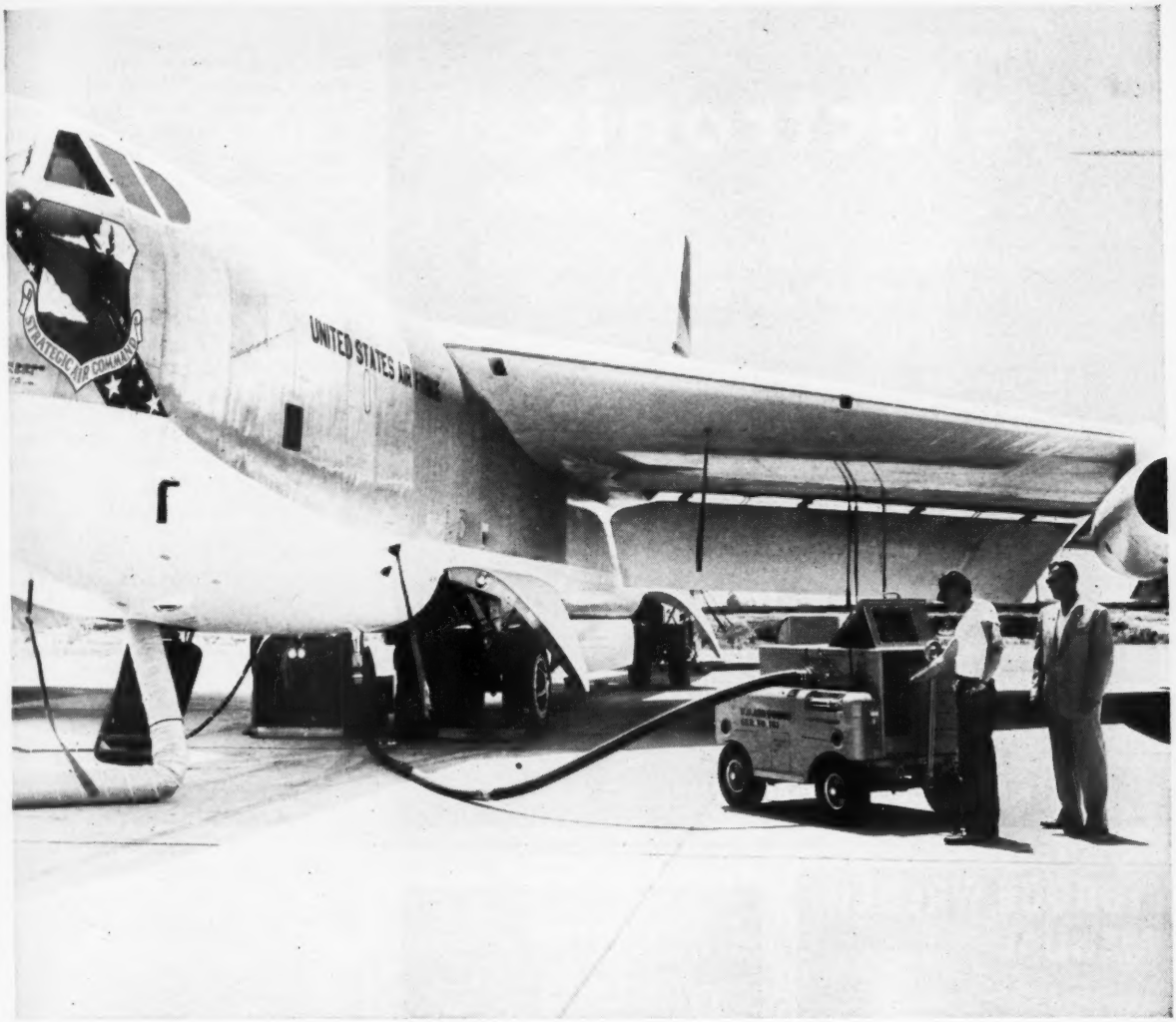


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Entirely self-contained, it furnishes a completely automatic source of compressed air power at the point of use. All components, parts and accessories are included in the fully-enclosed weather-proofed trailer.

The mobile unit weighs only 1150 pounds and may be controlled either from the instrument panel or from a remote control panel. It will start and maintain continuous operation at ambient temperatures ranging from −65°F to 130°F, together with the other extremes of environmental conditions encountered at airports throughout the world.

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numerical approximation, computer, and experimental approach.

To illustrate the advancement in design of helicopter blades, Mr. Duvivier brought along several blade sections. The most recent type was a laminated blade section. The resinous glue used in this section provides more strength than rivets.

When asked about his preference between research and industry, Mr. Duvivier had this to say. He personally would rather be building airplanes, but he feels that research is giving him a sound background. Doing research at M.I.T. has the added advantage of locating him in a situation in which he finds it a simple matter to carry on graduate study. One further advantage to the research situation, he feels, is that it is more leisurely as far as pressure for answers is concerned. There is more pressure in industry to produce.

During the business meeting, next year's officers were elected: Frank Cardone, Chairman; John Ladd, Vice-Chairman; Frank Nichols, Secretary-Treasurer.

ANNE EVEREST, *Secretary*

### Indiana Technical College

B. L. Dow, Faculty Adviser, presented the IAS Scholastic Award to

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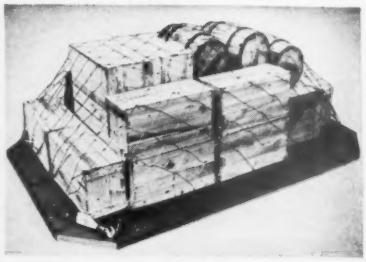
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Mr. Fukumoto at the June 26 meeting. Movies on *Lift* and *Drag* were shown.

At the June 12 meeting, Lloyd Wadekamper was appointed to replace Roy Krava as Chairman of the Awards Committee. A picnic was scheduled for July 15. A movie entitled *The Flying Wing* was shown.

Alfred Rathmell presided at both meetings.

WAYNE C. BOHANNON, *Secretary*

## Parks College of Aeronautical Technology

Thirty-two members attended the July 5 meeting at which Galen Johnston presided. The annual Student Scholastic Award was presented to Harry P. Mutter.

The following officers were elected: Chairman, Douglas Yando; Vice-Chairman, Dale Anderson; Secretary, Richard Andres; and Treasurer, John McCooey.

GERALD J. PANEK, *Secretary*

# MEMBERS ELECTED

*The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.*

### Elected to Associate Fellow Grade

**Ginsburg, Ambrose,** B.S.M.E., Branch Chief, Turbine Aero., Lewis Flight Propulsion Lab., NACA.

**Harris, Kenneth D.,** B.Sc. Engrg., Lecturer, Aerodynamics, College of Aeronautics (England).

**Weyl, A. R.,** Consultant in Aero. Engrg. (England).

### Transferred to Associate Fellow Grade

**Nagamatsu, Henry T.,** Ph.D. in Aero., General Electric Research Lab. (Schenectady); also Adjunct Prof. in charge of Hypersonic Experimental Research, Rensselaer Polytechnic Institute.

### Elected to MEMBER Grade

**Casey, Kenneth T.,** M.S.E.E., District Sales Mgr., General Electric Co. (Utica).

**Caughey, Reed J.,** B.S.A.E., Struct. Engr., Group Leader, Fuselage, Strength Sect., Douglas Aircraft Co., Inc. (Long Beach).

**Cole, Thomas E.,** B.S.M.E., Sr. Research Engr., Guided Missiles, North American Aviation, Inc. (Downey).

**Coppage, J. E.,** Ph.D. in M.E., Engrg. Specialist, AiResearch Manufacturing Co.

**Corrigan, Richard,** Group Engr., Douglas Aircraft Co., Inc. (Tulsa).

**Crowder, Jeffrey,** M.A., Deputy Head, Airframe Dept., English Electric Co., Ltd.

**Deschamps, Jacques R.,** Col., French Air Force, Member of French Delegation, NATO Standing Group (Pentagon).

**Devendorf, George L.,** B.S.M.E., Proj. Engr., Rheem Manufacturing Co.

**Dunn, E. Wallace,** S.B., Coordinator of Missiles Wind Tunnel Testing, Douglas Aircraft Co., Inc. (Santa Monica).

**Estes, Bruce H.,** B.S., Electronics Engr., McDonnell Aircraft Corp.

**Farmer, J. Elmo,** B.S., Tech. Asst., Allison Div., General Motors Corp.

**Heinze, D. M.,** Loft Linesman, Northrop Aircraft, Inc.

**Jacklin, Earl M.,** M.S.E.E., Systems Evaluation Engr., Advanced Design Sect., Douglas Aircraft Co. (Long Beach).

**Ketelsen, R. Paul,** V-P—Sales, Hydra Electric Co.

**Leong, Wing,** B.S.M.E., Head Stress Engr., The Emerson Electric Manufacturing Co.

**MacFee, Fred O., Jr.,** Mgr., Prelim. Design, General Electric Co. (Lynn).

**Matthews, James T.,** B.S. in Aero., Aero. Research Scientist, Stability & Control IV, Langley Field, NACA.

**Mead, John S.,** B.B.A., Sr. Operations Analyst, Convair, A Div. of General Dynamics Corp.

**Mitchell, James E.,** B.S., Loads Engr., McDonnell Aircraft Corp.

**Ollodort, M.,** B.S., Research Engr., North American Aviation, Inc. (Downey).

**Paterson, John H.,** Aerodynamics Engr., Lockheed Aircraft Corp.

**Potter, Donald L.,** B.S., Stress Analyst "A," Douglas Aircraft Co., Inc. (Long Beach).

**Pountney, Samuel,** Design Engr., Convair, San Diego, A Div. of General Dynamics Corp.

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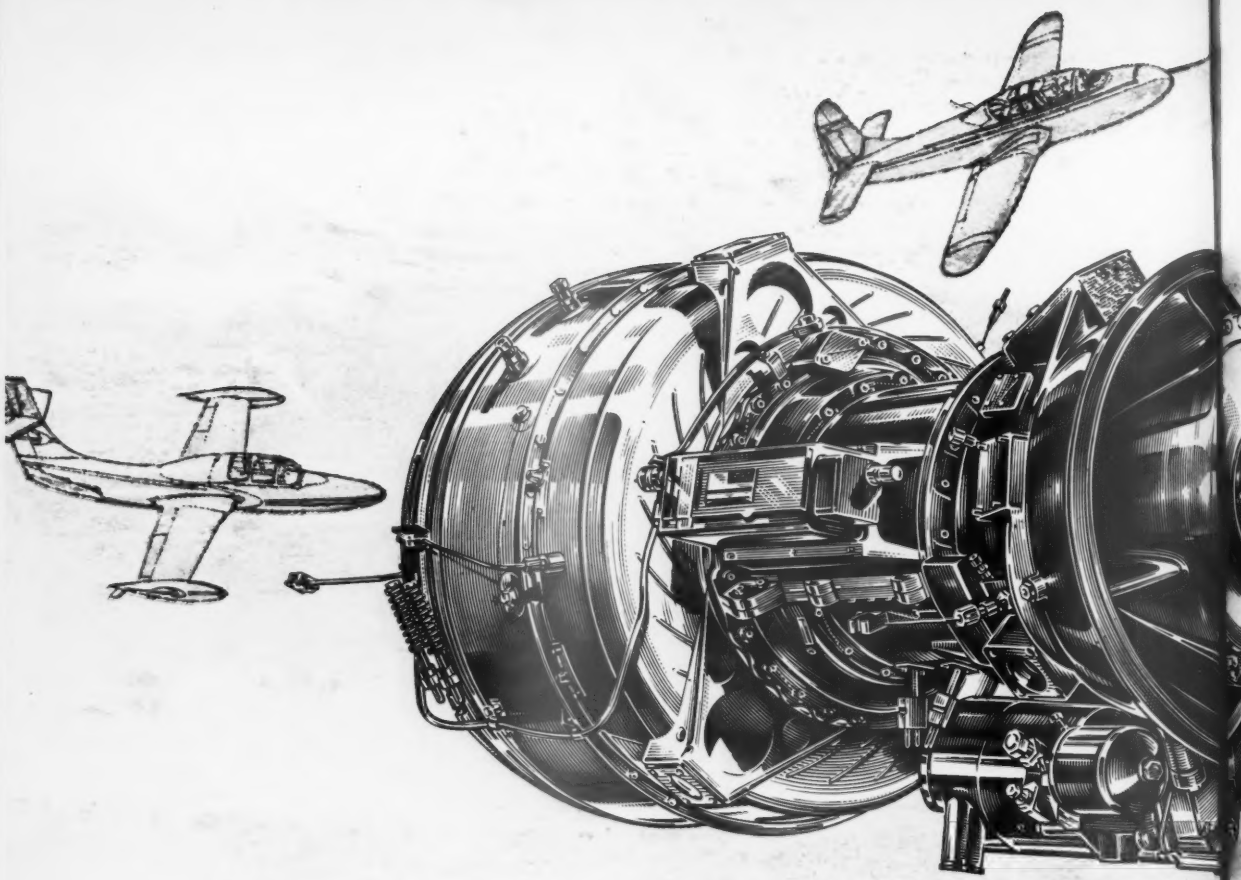

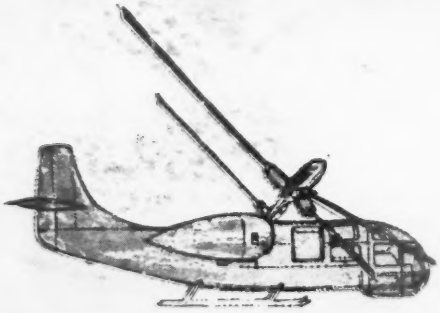

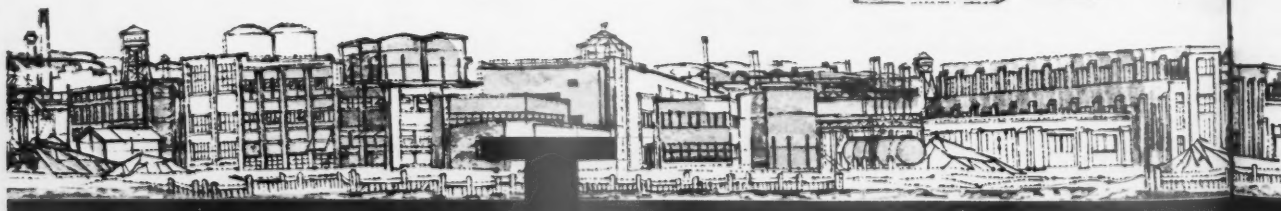

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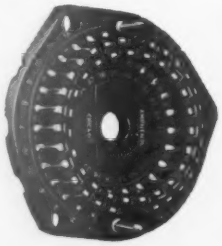

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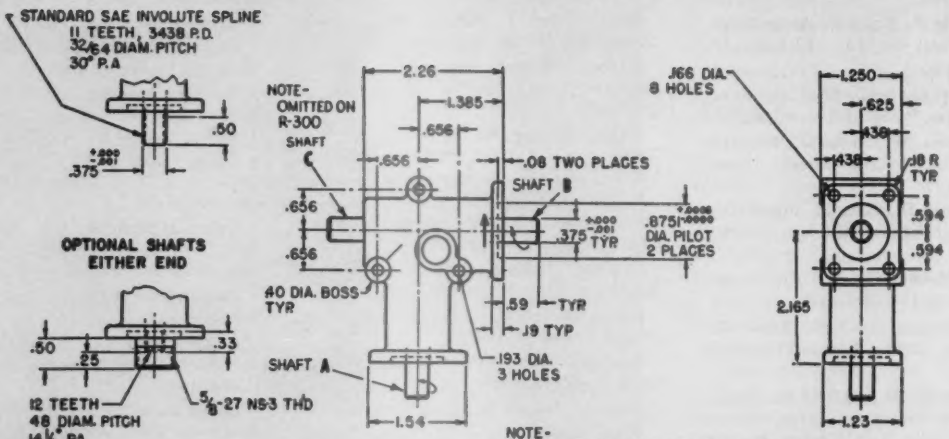


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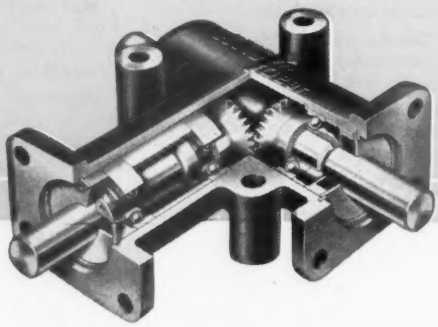

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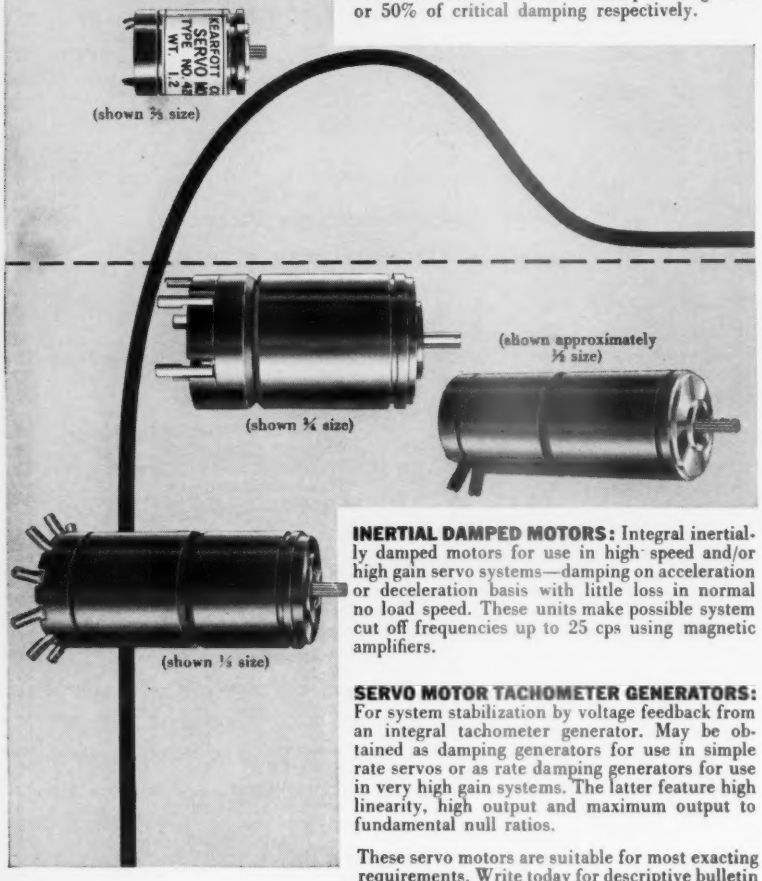


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## Acoustics, Sound, & Noise

**Noise, Vibration, and Aircraft Structures.** Arthur A. Regier. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 631.*) *Aero. Eng. Rev.*, Aug., 1956, pp. 56–61. 23 refs. Review of the basic factors in terms of the response of systems to various types of input, near field characteristics of various noise sources, vibration modes, and fatigue.

**Theory of the Rocket-Grenade Method of Determining Upper-Atmospheric Properties by Sound Propagation.** G. V. Groves. *J. Atmos. & Terrestrial Phys.*, May, 1956, pp. 189–203.

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## Aerodynamics

### *Aerothermodynamics*

**Heat Transfer in Compressible Laminar Boundary Layers. I.** S. Lal. *J. Aero. Soc. India*, Feb., 1956, pp. 1–17. 23 refs. Analysis of skin friction and heat transfer in a two-dimensional compressible boundary layer without restrictions on Mach Number, Prandtl Number, or pressure gradient in the external flow.

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**Boundary Layer.** L. G. Loitsianskii. (Translation from Mechanics in the USSR Over Thirty Years, 1917–1947, pp. 300–320.) *U.S., NACA TM 1400*, May, 1956. 29 pp. 70 refs. Comprehensive bibliography covering research in USSR, with a review of the most important results obtained in the development of the theory of the boundary layer.

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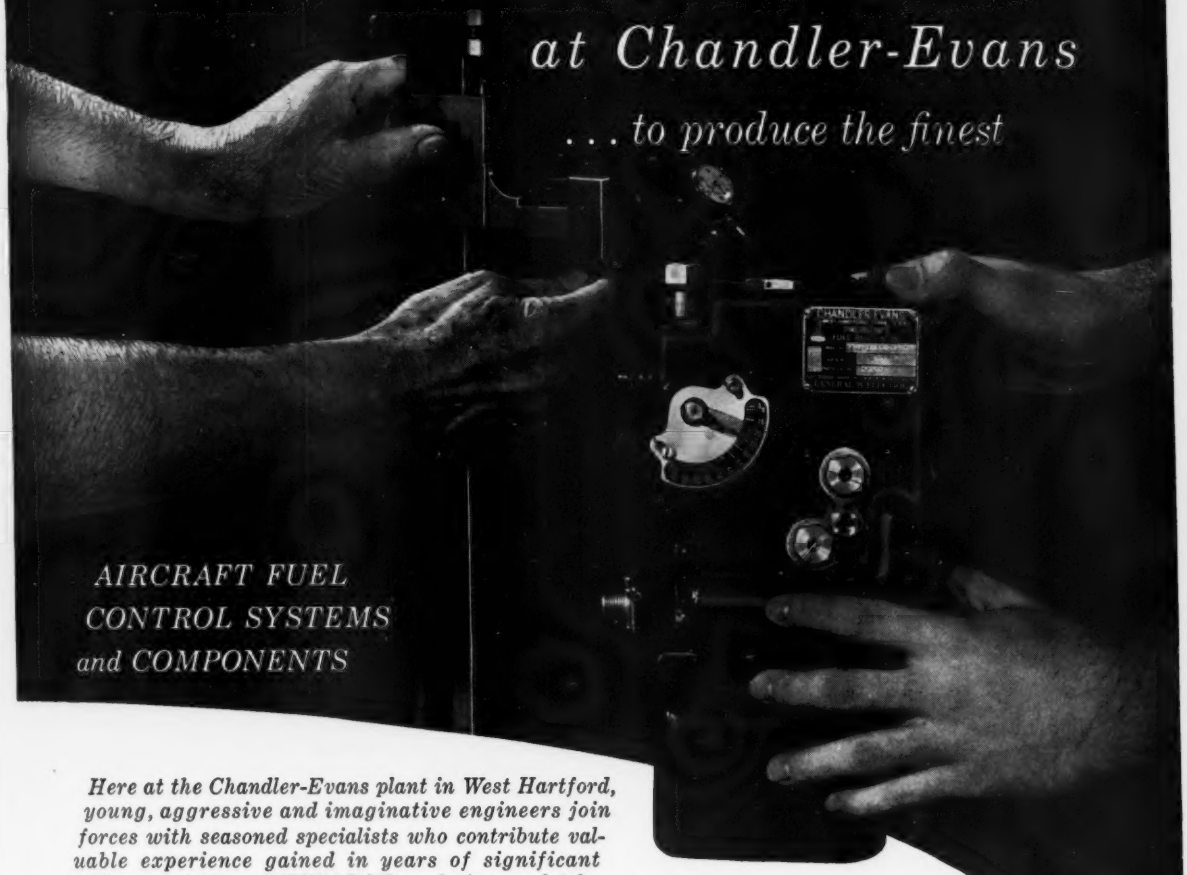

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**The Laminar Boundary Layer on Oscillating Plates and Cylinders.** M. B. Glauert. *J. Fluid Mech.*, May, 1956, pp. 97–110. Theoretical investigation of the two-dimensional, laminar boundary layer on an infinite plate normal to an oncoming stream, the plate making transverse oscillations in its own plane, and derivation of a solution, containing the frequency of oscillation as a parameter and depending on a single, ordinary differential equation which satisfies the full Navier-Stokes equations.

**On the Boundary-Layer Equations of a Very Slender Body of Revolution.** S. I. Pai. *J. Aero. Sci.*, Aug., 1956, pp. 795, 796. Solution of boundary-layer equations of a steady, axially symmetric compressible fluid flow over a body of revolution whose radius is of the same magnitude as the thickness of the boundary layer.

**Couche Limite Turbulente: Corrélations Spatio-Temporelles Doubles, Spectres.** A. Favre, J. Gaviglio, and R. Dumas. *La Recherche Aéronautique*, Nov.-Dec., 1955, pp. 3–14. 11 refs. In French. Measurements of longitudinal components of velocity in the boundary layer on a flat plate with zero pressure gradient. The transition is initiated either by controlled turbulence downstream of the plate or by asperities on the leading edge.

**Grenzschichtuntersuchungen an zwei schiebenden, unendlich langen Flügeln in inkompressibler Strömung.** K. Nickel. *DFL Inst. für Aero. Bericht No. 56/12*, Apr. 18, 1956. 41 pp. In German. Investigation of the boundary layer on two yawed, infinitely long airfoils in incompressible flow.

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**Some Further Jet Flap Experiments.** N. A. Dimmock. *Gt. Brit., NGTE Memo. M.255*, May, 1956. 70 pp. Extension of Dimmock's results of experiments on a two-dimensional airfoil with a 12.5 per cent thick elliptical cross section with a narrow full-span jet slot, to the same type of airfoil with the jet deflection 58.1° from the chord line.

### *Fluid Mechanics & Aerodynamic Theory*

**Mixed-Type Conical Flow Without Axial Symmetry. (Summary of the Recent Work Performed at PIBAL.)** Antonio Ferri, Roberto Vaglio-Laurin, and Nathan Ness. *Polytech. Inst. Bklyn. Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 264*, Dec., 1954. 39 pp. OSR-supported analysis of conical flow problems. A characteristic method is developed which permits rapid numerical calculations of the hyperbolic region. The transonic region is analyzed from a mathematical and physical point of view.

**The Slender Elliptic Cone as a Model for Non-Linear Supersonic Flow Theory.** M. D. Van Dyke. *J. Fluid Mech.*, May, 1956, pp. 1–15. 19 refs.

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**Les Mesures d'Ondes de Choc.** J. Mattei. *La Recherche Aéronautique*, Mar.-Apr., 1956, pp. 39–44. In French. Schematic presentation of the pressure evolution in several types of perturbations, and simplifying representation of the phenomena by a mathematical curve. Includes a description of the ONERA ballistic-wave flight-measurement program covering the calculation of shock waves, and an analysis of the possible structure of pressure oscillations for the determination of the frequency range transmitted by the measuring apparatus.

**Diffraction of a Weak Shock with Vortex Generation.** Nicholas Rott. *J. Fluid Mech.*, May, 1956, pp. 111–128. 12 refs. OSR-supported theoretical investigation of the region of finite vorticity near the edge of a diffracting wedge, including a dimensional analysis of the dependence of the circulation and the velocity of the vortex region on the pulse strength, and an estimate of the magnitude of these quantities obtained by replacing the vortex region by a single concentrated vortex.

**Vibrational Relaxation in Oxygen and Nitrogen.** Vernon Blackman. *J. Fluid Mech.*, May, 1956, pp. 61–85. 17 refs. Experimental investigation to determine the state variables for a strong shock wave whose Mach Number is so high that the approximation of constant specific heats is no longer applicable and to measure, wherever possible, the relaxation times for the approach to equilibrium behind the shock.

**Application of Scattering Theory to the Measurement of Turbulent Density Fluctuations by an Optical Method.** Appendix A—**Relationship Between Dielectric Fluctuations and Density Fluctuations for Air.** Appendix B—**Telephotometer Equation for the Case of a Gaussian Correlation Coefficient.** Howard A. Stine and Warren Winovich. *U.S., NACA TN 3719*, June, 1956. 21 pp. 10 refs.

**Viscous Dissipation in Turbulent Motion.** Max M. Munk. *Catholic U. of Am., Paper*, June, 1956. 27 pp. ONR-supported analytical investigation to derive the correct expression for the rate of dissipation, with a comparison with the pseudodissipation used in turbulence research, and an estimation of the error introduced by the substitution of the pseudodissipation. Includes discussion of the Laufer pipe and channel tests with computation of some relations from the results.

**Ein Verfahren zur Untersuchung des Austauschvorganges in verwirbelten Strömungen hinter Körpern mit abgelöster Strömung.** A. W. Quick. *DVL Bericht No. 12*, Mar., 1956. 34 pp. Westdeutscher Verlag, Köln & Opladen DM 8.70. In German. Development of a method for the solution of the exchange process between the outside flow and the flow in the vortex behind blunt bodies.

### *Internal Flow*

**An Analysis of the Performance on an Axial-Flow Compressor at Low Reynolds Number.** Robert L. Sohn. *J. Aero. Sci.*, Aug., 1956, pp. 741–746, 791. Theoretical study of compressor performance taking into account the behavior of the boundary

layer attached to the blades. The theory suggests that the blade boundary layer forms a laminar separation bubble shortly downstream of the point of minimum pressure, reattaching itself in turbulent form after the transition has taken place.

**Ergebnisse systematischer Untersuchungen an ebenen Schaufelgittern. V—Vergleich der Geschwindigkeitsverteilung nach Rechnung und Messung bei Pumpengittern aus Laminarprofilen.** O. Saffet Müftüoglu. *Braunschweig Tech. Hochschule Inst. Strömungsmech., Rep. 54/18*, Aug. 23, 1954. 38 pp. In German. Comparison of the Schlichting numerical method for calculating the potential flow in cascades with Bogdonoff pressure distribution measurements on pump blading in laminar profiles.

**Berechnung der reibungslosen inkompressiblen Strömung für ein vorgegebenes ebenes Schaufelgitter.** Hermann Schlichting. *VDI-Forschungsheft 447*, 1955. 47 pp. 27 refs. In German. Development of a simple method, based on the method of singularities in which each blade of the cascade is replaced by a continuous vortex and source distributions, to permit the varying of any of the geometric parameters independently of others and to provide theoretical means for investigating systematically the dependency of aerodynamic parameters on geometric parameters.

**On the Wake Energy of Moving Cascades.** N. H. Kemp and W. R. Sears. *J. Appl. Mech.*, June, 1956, pp. 262–268. OSR-supported analysis of the rate of energy transfer into kinetic energy of the vortex wakes for unsteady, two-dimensional flow in cascades of thin airfoils, as applied to an elementary compressor stage consisting of two rows of blades in relative motion.

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**The Calculation of Converging Channels.** G. Moretti. (*Aero. Argentine Commun. & Inform.*, Nov. 29, 1954.) *Gt. Brit. MOS TIL/T4612*, Apr., 1956. 17 pp. Translation. Description of a new "mixed method" procedure and a comparison with the hodograph and general methods.

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**The Oscillations of a Supersonic Gas Jet Embedded in a Supersonic Stream.** D. C. Pack. *J. Aero. Sci.*, Aug., 1956, pp. 747–753, 764. Theoretical analysis, based on the linearized equation of steady motion in gas dynamics, of both two-dimensional and axially symmetrical jets. The analysis of the oscillations for the two-dimensional case sets up the procedure and presents the findings of Pai and Kawamura in a general form, while illustrating some new features. A comparison is made between the reflection and transmission phenomena in the two-dimensional and axially symmetrical cases, and the flow near to and at a large distance from the orifice from which the jet flows is examined.

**Velocity Discontinuity Instability of a Liquid Jet.** B. Dunne and B. Cassen. *J. Appl. Phys.*, June, 1956, pp. 577–582. Theoretical and experimental investigation of the origins and behavior with time of the velocity discontinuity instability which occurs when the liquid reservoir from which the jet issues is subjected to shock-wave pressure, with a resultant discontinuous increase in jet velocity and appearance of a thin disc of liquid, normal to the jet axis, at the discontinuity.

**On the Thrust Due to an Air Jet Flowing from a Wing Placed in a Wind Tunnel.** L. C. Woods. *J. Fluid Mech.*, May, 1956, pp. 54–60.

**Sur une Propriété Simple d'Adaptation Optimale des Éjecteurs Supersoniques.** E. Le Grivès and J. Paulon. *La Recherche Aéronautique*, Mar.-Apr., 1956, pp. 27–30. In French. Calculation of supersonic ejectors applied to wind-tunnel and simulated altitude research and to devices for the augmentation of thrust and of circulation over the airfoils, with a comparison of experimental and theoretically predicted results.

### *Wings & Airfoils*

**The Effects of Compressibility on the Upwash at the Propeller Planes of a Four-Engine Tractor Airplane Configuration Having a Wing with 40° of Sweepback and an Aspect Ratio of 10.** Armando E. Lopez and Jerald K. Dickson. *U.S., NACA TN 3675*, July, 1956. 38 pp.

**Calcul d'un Profil Symétrique en Écoulement Incompressible.** H. Guennoc. *La Recherche Aéronautique*, Mar.-Apr., 1956, pp. 13–15. In French. Development of a method for the calculation of symmetrical laminar profiles having such previously determined geometrical characteristics as the radius of curvature of the leading edge, the dihedral at the trailing edge, and the positions as function of the potential. Legendre method for subsonic speeds is applied.

**Der gewölbte und verwundene Tragflügel ohne Dicke in Schallnähe.** F. Keune. *DVL Bericht No. 13*, Apr., 1956. 30 pp. 15 refs. Westdeutscher Verlag, Köln & Opladen. In German. Derivation of aerodynamic data for cambered and twisted airfoils as an extension of the Jones theory of plane or pointed wings of low aspect ratio.

**Application de la Théorie des Mouvements Homogènes au Calcul des Effets de Portance Pour des Ailes en Flèche Effilées.** M. Fenain and D. Vallée. *La Recherche Aéronautique*, Mar.-Apr., 1956, pp. 17–25. In French. Application of the theory of homogeneous motion to the calculation of the effects of lift on delta wings.

**Prediction of Downwash at Various Angles of Attack for Arbitrary Tail Locations.** James L. Decker. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 615.*) *Aero. Eng. Rev.*, Aug., 1956, pp. 22–27, 61. 10 refs.

**Application of Drag-Reduction Methods to Supersonic Biplanes.** Appendix—**Alternative Proof of Non-Interference of Certain Symmetric and Antisymmetric Lift and Volume Distributions.** M. E. Graham. *Douglas Rep. SM-19258*, Sept., 1955. 74 pp. 14 refs.

**The Optimum Distribution of Lift in Certain Prismatic Regions at Supersonic Speed.** William W. Willmarth. *J. Aero. Sci.*, Aug., 1956, pp. 800, 801.

**Exact and Approximate Solutions for the Supersonic Delta Wing.** L. R. Fowell. *J. Aero. Sci.*, Aug., 1956, pp. 709–720, 770. 14 refs. Results of a theoretical investigation to obtain an exact solution of the equations governing steady inviscid supersonic flow with constant stagnation enthalpy about an infinitely thin flat delta wing with supersonic leading edges at a finite angle of attack and zero angle of yaw—a problem in exact cone field theory. The methods used are indicated.

**Tests in the R.A.E. 10-ft × 7-ft High Speed Wind Tunnel on Drop Tanks Fitted to Two Swept-Back Wings. I—Comparison of Under-Wing and Wing-Tip Installations.** D. E. Hartley and A. B. Haines. **II—Comparison of Various Under-Wing Drop-Tank Arrangements.** Staff of R.A.E. High Speed Wind Tunnel. *Gt. Brit., ARC R&M 2951* (July, 1952), 1956. 45 pp. 17 refs. BIS, New York, $2.25.

## Aeroelasticity

**Aeroelastic Problems of Low Aspect Ratio Wings. V—Application of the Structural and Aeroelastic Matrices to the Solution of Steady State Aeroelastic Problems.** J. E. F. Farbridge, F. A. Woodward, and G. E. A. Thomann. *Aircraft Eng.*, June, 1956, pp. 196–198.

**The Behaviour of Damped Linear Systems in Steady Oscillation.** R. E. D. Bishop. *Aero. Quart.*, May, 1956, pp. 156–168. Description of a theoretical method which assumes hysteretic rather than viscous damping, whereby the nature of damped vibration can be demonstrated in general terms. Includes a brief summary of the relevant features of the theory of undamped systems and an

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analysis of the hysteretic damping of systems with $n$ degrees of freedom and of systems with small damping.

**Modification des Formes Propres d'une Structure par l'Addition de Petites Masses.** J. Leclerc. *La Recherche Aéronautique*, Mar.-Apr., 1956, pp. 45–50. In French. Modification of natural shapes of a structure by addition of small masses, used in the determination of the aircraft critical speed.

**Numerical Results for the Longitudinal Stability Derivatives and Stability Loci of a Low Aspect Ratio Rectangular Wing in Supersonic Flow.** Lee Winograd and John W. Miles. *Aero. Quart.*, May, 1956, pp. 106–108.

**A Method for the Solution of Instability Problems; Analysis of Pencils of Singular Hermitian Matrices.** J. P. O. Silberstein. *Australia, ARL Rep. SM.233*, Sept., 1955. 32 pp. Description of a procedure applicable to cases in which convergence difficulties require the use of high-order matrices.

**On the Aerodynamic Instability of Thin Panels.** John W. Miles. *J. Aero. Sci.*, Aug., 1956, pp. 771–780. 16 refs. Analysis of self-excited motion of an infinite, approximately plane, thin panel placed in compressible flow, using linearized theory.

**High-Frequency Extensional Vibrations of Plates.** T. R. Kane and R. D. Mindlin. *J. Appl. Mech.*, June, 1956, pp. 277–283. Derivation of differential equations and boundary conditions taking into account the coupling between the extensional motions and the first mode of thickness vibration. A solution is given for the axially symmetric vibrations of a circular disc and is compared with experimental data.

**A Method of Solution for Lateral Vibrations of a Nonuniform Bar and a Circular Plate with Variable Thickness.** Hisao Takeyama. *J. Japan Soc. Aero. Eng.*, May, 1956, pp. 1–7. 13 refs. In Japanese. Development of a method for solving analytically the lateral vibration equation of nonuniform bars subjected to axial forces, and of circular plates with variable thickness, which may be stressed axisymmetrically by rotation about their axis and heating, by transforming them into Volterra integral equations of the second type.

**Some Integrals Relating to the Vibration of a Cantilever Beam and Approximation for the Effect of Taper on Overtone Frequencies.** A. I. Martin. *Aero. Quart.*, May, 1956, pp. 109–124.

## Airplane Design

**Military Aircraft 1956.** *Flight*, June 8, 1956, pp. 699–758. Detailed breakdown by companies and design types of approximately 160 fighters, ground attack and fighter bombers, and reconnaissance, ship-borne antisubmarine, transport, and trainer aircraft.

**Gewichtsunterlagen für den Flugzeugentwurf.** O. Köhler. *Luftfahrttechnik*, Dec. 15, 1955, pp. 134–139. In German. Analysis of the weight problem in aircraft construction including wing assembly, fuselage, additional weight for pressurized cabins, tail assembly, control systems, and landing gear.

**The Comet 4 Design and Operational Considerations.** R. E. Bishop and J. Cunningham. (*CAI Annual Gen. Meeting, Montreal, May 4, 1956.*) *Can. Aero. J.*, June, 1956, pp. 197–206. An account of the Comet 4 capabilities, structural design, engine installation, control systems, some of the more important improvements over earlier aircraft, and Comet flying experience.

**The Vickers Viscount.** J. H. Sinclair. *J. SLAE*, May, 1956, pp. 3–12, 18, cutaway drawings. Abridged. General discussion of the Vickers Viscount aircraft, with description of the "630" and "700" prototypes, the performance of the "700," and the Viscount's electrical installation. Includes a review of the closely related development of the Dart and the Viscount engines and an outline of plans for the next decade.

**Vickers Vanguard; Preliminary Details of Commercial and Design Characteristics.** *Flight*, June 1, 1956, pp. 671–676. Includes a detailed description of the structure, turboprop power plants, pay-load accommodation, fuel and hydraulic systems, flying controls, pressurization and air-conditioning systems, deicing, and overall performance and weights.

**Westland Wyvern; Design and Development of the Navy's Turboprop Strike Aircraft.** *Flight*, June 15, 1956, pp. 774–779, cutaway drawings.

### *Air Conditioning & Pressurization*

**An Expander-Compressor Method of Air Cooling.** R. S. Macdonald. *Cornell Aero. Lab. PR HG-591-S-2*, Dec. 21, 1954. 21 pp. Development of a method of air cooling which reduces the air temperature by an adiabatic expansion through an expansion turbine.

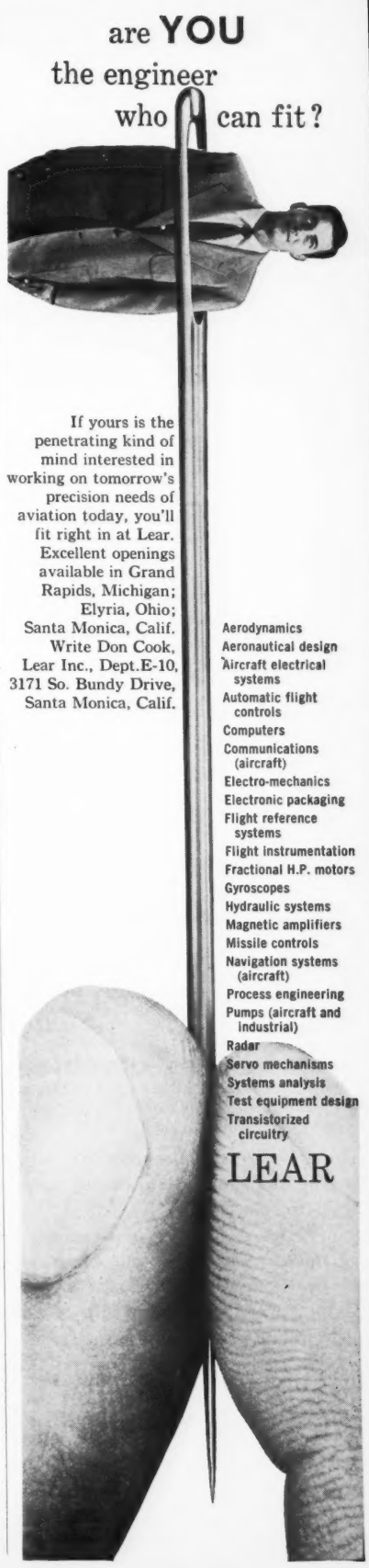
**A Survey of Possible Refrigerants for High-Temperature Application.** J. Van Winkle. *ASME Semi-Annual Meeting, Cleveland, June 17–21, 1956, Paper 56-SA-12.* 6 pp. Results of the refrigerant study indicate that mercury and alkali metals, "Nak" alloy, and fluorinated-chlorinated hydrocarbon compounds are the best materials for conventional vapor-cycle systems operating at high sink temperatures required in supersonic air frames.

**A Comparison of Refrigerants When Used in Vapor Compression Cycles Over an Extended Temperature Range.** J. P. Barger, W. M. Rohsenow, and K. M. Treadwell. *ASME Semi-Annual Meeting, Cleveland, June 17–21, 1956, Paper 56-SA-6.* 5 pp.

**Turboconditioning Systems with Vapor Compression Cycles.** J. P. Barger, W. M. Rohsenow, and K. M. Treadwell. *ASME Semi-Annual Meeting, Cleveland, June 17–21, 1956, Paper 56-SA-7.* 17 pp. Comparison of the relative performance and possible configurations of turboconditioning systems for cooling supersonic aircraft. Numerical values for the performance of eight different system arrangements at Mach Numbers 2, 3, and 4 are presented.

### *Landing Gear*

**Landing Gear Design.** Harry M. Turner. *Aero Dig.*, May, 1956, pp. 36–38, 40. Description of a preventive engineering plan emphasizing the service life factors and fatigue requirements.

**The Constellation Landing Gear.** *Lockheed Field Serv. Dig.*, May-June, 1956, pp. 1–14. Description of components, features, and geometry of the landing gear; outline of important adjustment checks; discussion of emergency operation procedures to be carried out at unsafe landing gear indications; and certain maintenance recommendations.

*Operation & Performance*

**YC-121F Limited Phase II Performance Evaluation.** Lee H. Erb and Reese S. Martin. *USAF FTC TR 56–9*, June, 1956. 50 pp. Performance analysis of a standard transport aircraft modified as a test-bed for Pratt and Whitney T-34-P-6 turboprop engines.

**The Turbine-Propeller Combination in the Air Force.** Roy J. Wellman. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 584.*) *Aero. Eng. Rev.*, Aug., 1956, pp. 40–43, 61.

## Aviation Medicine

**The Development of the Pressure Suit for High Altitude Flying.** T. W. Walker. *Project Engr.*, May, 1956. 10 pp. Review of developments in pressure suit design in the United States, England, France, Italy, and Germany from 1920 to 1945.

**The Human Pilot and the High-Speed Airplane.** James L. Decker. *J. Aero. Sci.*, Aug., 1956, pp. 765–770. Theoretical investigation into human dynamics as it affects the airplane in pitch, in order to derive a method of predicting the pilot transfer function during pitching flight. The longitudinal stability of the human-pilot-aircraft combination is detailed, taking into consideration the type of control the pilot attempts to apply and the physiological factors of reaction time and muscular lag.

**Transthoracic Pressure in Man During Rapid Decompression.** Ulrich C. Luft and Richard W. Bancroft. *Av. Med.*, June, 1956, pp. 208–220. 24 refs.

**The Direct Interpretation of the Fast Vital Capacity Record.** R. J. Shephard. *Gt. Brit., RAE FPRC Rep. 956*, Feb., 1956. 32 pp. 22 refs. Examination of errors underlying the spirometer measuring method, and study of the stability of various F.V.C. parameters by repeated pneumotachograph measurements on a small group of normal subjects.

## Computers

**The Integrated Use of Analog and Digital Computing Machines for Aircraft Dynamic Load Problems.** Bernard Mazelsky and Robert F. O'Connell. *J. Aero. Sci.*, Aug., 1956, pp. 721–740, 780.

**Analog-to-Digital Conversion.** Martin L. Klein, Frank K. Williams, and Harry C. Morgan. *Instruments & Automation*, May, 1956, pp. 911–917. Description and comparison of the time, voltage, feedback, and space encoding techniques in terms of their principles and operation.

**Electric Analogies for Mechanical Structures.** Gilbert D. McCann. *ISA J.*, May, 1956, pp. 161–164. Comparison of loop and nodal types, and detailed consideration of the nodal system in terms of the general form of RLC nodal circuits, properties of line coordinate transformations, equations of constraint, and distributed elastic systems.

**Process Data Logging Systems.** Robert J. Marmorstone. *Instruments & Automation*, May, 1956, pp. 890–894. Includes the use of electromechanical and electronic techniques for multiplication, square-root extractions, integration, time compensation, and analog-to-digital conversion. Special features: automatic testing and standardization.

**Reflected Number Systems.** Ivan Flores. *IRE Trans., EC Ser.*, June, 1956, pp. 79–82. Extension of the method used in creating the reflected binary system, description of the composition of reflected systems of different bases, and derivation of equations for translating between the conventional and reflected systems.

**A One-Microsecond Adder Using One-Megacycle Circuitry.** A. Weinberger and J. L. Smith. *IRE Trans., EC Ser.*, June, 1956, pp. 65–73.

**Die Verwendbarkeit eines Elektronischen Zählgerätes zur Messung von Mengen, Zeiten und Frequenzen sowie zur Impulsgabe.** A. Becker. *DFL Braunschweig, Inst. Luftfahrzeugf. Bericht 46–55/9*, Oct. 1, 1955. 18 pp. In German. Analysis of the applicability of an electronic computer to measurements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of quantities, time, frequency, and momentum in the electronic, thermal, acoustic, and optical fields.

**A General Purpose Electronic Multiplier.** Robert A. Mayers. *U.S., Navy Dept., David W. Taylor Model Basin, Rep. 938,* Apr., 1955. 35 pp. Description of the electronic multiplier circuit used in conjunction with other electronic devices to comprise a special type of analog computer, with details of design, operating characteristics, and construction.

**Analog Computer for the Engineer.** John M. Carroll. *Electronics,* June, 1956, pp. 122–133. Discussion covering computer parts, differences, supplementary equipment, accuracy, amplifier circuits, and analog multiplication. Further includes characteristics of various computers and a chart of computer amplifier performance.

**Tridac, a Large Analogue Computing Machine.** F. R. J. Spearman, J. J. Gait, A. V. Hemingway, and R. W. Hynes. (*IEE Paper 1899 M.*) *Proc. IEE, Part B,* May, 1956, pp. 375–390; Discussion, pp. 390–395. 12 refs. Description of the RAE machine, including principles of operation, computing methods and components, and installation. The apparatus has electronic, mechanical, and hydraulic components, operates on a 1:1 time scale so that the real components can be included in the computation, and was built to assist in solving guided-weapon problems by constructing system models for mathematical calculations.

**The Direct Analogy Electric Analog Computer.** Gilbert D. McCann. *ISA J.,* Apr., 1956, pp. 112–118. 43 refs. Description of the apparatus, with an evaluation of the basic techniques of general circuit synthesis.

**Principles and Application of Electronic Analogue Computers. III, IV.** P. Heggs. *Electronic Eng.,* May, June, 1956, pp. 212–215, 257–259.

**Analog Multipliers and Squarers Using a Multigrid Modulator.** R. L. Sydnor, T. R. O'Meara, and J. Strathman. *IRE Trans., EC Ser.,* June, 1956, pp. 82–85. 17 refs. Description and evaluation of a device having a usual range of 78 db., whose accuracy is solely dependent upon the linear properties of the vacuum tube used.

**Transistors in Current-Analog Computing.** Branch P. Kerfoot. *IRE Trans., EC Ser.,* June, 1956, pp. 86–93. Description of experimental direct-coupled amplifiers, with an analysis of the factors determining computer accuracy and a discussion of a new error-prediction technique based on square-wave output.

**Application of Electrical Analogy for the Solution of Problems in Elasticity.** V. Cadambe and S. G. Tewari. *J. Sci. & Ind. Res., Sect. B,* Mar., 1956, pp. 107–111. Description of the device and its components and of the technique used to measure the potential distribution in order to solve the Laplace equation, with an illustration of its application to the problem of bending prismatic triangular bars.

**Practical Analog-Digital Converters.** Martin L. Klein, Frank K. Williams, and Harry C. Morgan. *Instruments & Automation,* June, 1956, pp. 1,109–1,117. Description of devices designed for shaft-position conversion with binary and uncoded outputs, direct data printing, data loggers with all-electronic conversion, and all-electronic high-speed conversion.

**A New Serial Digital Decoder.** S. V. Soanes. *Electronic Eng.,* June, 1956, pp. 247–249. Description of a device which is virtually independent of the frequency of the clock timing pulses and which, since it is fundamentally a polynomial generator, can also be used in analog computers to solve certain types of polynomial equations.

**Transistor Digital Computers (New Binary Circuit Techniques Described at I.E.E. Convention).** *Wireless World,* May, 1956, pp. 210–212. Evaluation of transistors used in digital computers for driving two-state magnetic storage coils and for acting as two-state pulse amplifiers.

**A Digital Differential; Simultaneous Bi-Directional Counting Using a Dekatron.** W. H. P. Leslie. *Electronic Eng.,* May, 1956, pp. 190–193. Description of the circuit using a Dekatron to indicate the running difference in count between two independent pulse trains. The circuit is applied to indicate frequency differences, to generate difference frequency signals without tuned circuits, and to control frequency or speed relative to a master signal.

**USAF Computer Uses Magnetic Amplifiers.** *Electronics,* July, 1956, pp. 138, 139. Description of a digital computer using magnetic amplifiers for power gain. Tape-wound cores on stainless-steel bobbins are used to overcome frequency limitation of magnetic devices.

**Engineering and Scientific Applications of Digital Computers.** *The Engr.,* Apr. 20, 1956, pp. 372, 373.

**A Transportation Simplex Algorithm for Machine Computation Based on the Generalized Simplex Method.** George Suzuki. *U.S., Navy Dept., David W. Taylor Model Basin, Rep. 959,* June, 1955. 17 pp.

**Introduction to Flac Coding.** R. J. Koning. *USAF MTC TR-56-8,* July, 1954. 117 pp. Study of programing and coding operations in an electrical digital computer used for transforming flight-test data.

**The Electronic Digital Computer in Aircraft Structural Analysis; The Programming of the Argyris Matrix Formulation of Structural Theory for an Electronic Digital Computer. III—General Purpose Programmes for the Force and Displacement Methods in Large Structures Including the Use of Magnetic Tape Storage.** P. M. Hunt. *Aircraft Eng.,* May, 1956, pp. 155–165.

**Random Time-Modulation of the Main Bang for Increased Accuracy in Digital Range Measurement.** Lee B. Harris. *IRE Trans., ANE Ser.,* June, 1956, pp. 84–90. Analysis of the accuracy of the random time-modulation method in the presence of gate jitter to show that it can effectively reduce the resolution error.

## Education & Training

**Flight Application of Target-Simulator Principles.** William M. Kauffman. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 649.* 9 pp. Members, $0.35; nonmembers, $0.75. Description of equipment developed at the Ames Aeronautical Lab. for use in the fields of training, systems development, and instrument flight, and a discussion of motion picture techniques for evaluating tracking errors.

**A Comparative Study of the Attitudes of Student Groups in Advanced Flying Training.** John T. Lanzetta and Dorothy M. Knoell. *USAF PTRC TN 55-30,* Oct., 1955. 21 pp. Evaluation of the "Project Tiger" advanced-flying training program, initiated to enhance motivation of flying personnel and to increase re-enlistment, decrease self-elimination, and reduce the number of fear-of-flying cases.

**Multiple Response Transfer as a Function of Supplementary Training with Verbal Schematic Aids.** Frederick H. Kresse, Robert M. Peterson, and David A. Grant. *USAF PTRC TN 55-34,* Oct., 1955. 10 pp.

## Electronics

**1956 Electronic Industries Directory.** *Tele-Tech,* June, 1956, pp. 213–308. Detailed reference guide covering products and manufacturers.

**Electronic Procurement—Production Directory.** (Electronic Industries 1956 Exclusive Military Procurement-Production Organization and Directory of Key Air Force, Navy and Army Personnel.) R. M. Johnson. *Tele-Tech,* July, 1956, pp. 81–95.

**Thermistor Applicator.** *Aerovox Res. Worker,* May-June, 1956. 5 pp. Description of typical characteristics, illustrative circuits, temperature control, time delay, voltage regulator, vacuum gage, flowmeter, sequence-switching circuit, lockout switching system, amplifier feedback, limiter, expander, and UHF microwave wattmeter.

**Čerenkov Radiation from Extended Electron Beams Near a Medium of Complex Index of Refraction.** Herbert Lashinsky. *J. Appl. Phys.,* June, 1956, pp. 631–635. USAF-Army-Navy-supported analysis.

### *Amplifiers*

**The Impedance Concept. II—Quartic and Quintic Characteristic Equations: Maximum Feedback.** C. G. Mayo and J. W. Head. *Wireless Engr.,* May, 1956, pp. 121–128. Detailed analysis of the effect on stability and damping of adding terms in the Heaviside operator, $p$, carried to the fourth and fifth power, with a discussion of the addition of extra step-circuit elements to a three-stage r.c. amplifier in order to improve the feedback. Includes a graphical method of evaluating the parameters associated with the additional elements which may be used to obtain a given amount of feedback.

**Cascode A.F. Amplifier; "Long-Tailed Cascode Pair" as Combined Pre-Amplifier and Phase Splitter.** L. B. Hedge. *Wireless World,* June, 1956, pp. 283–287. Development of a cascode amplifier employing a feedback loop with two r.c. coupling networks, and an output transformer with a maximum phase shift of 270°.

**All-Transistor Servo Amplifier.** Edward D. Pagdett. *Elec. Mfg.,* June, 1956, pp. 145–149, 342, 343. Developmental

discussion leading from practical transistor specifications to an experimental 24-volt d.c. amplifier directly coupled to the control winding of a modified servomotor.

**Docile Behavior of Feedback Amplifiers.** S. J. Mason. *Proc. IRE*, June, 1956, pp. 781–787. USAF-Army-Navy-sponsored simplified geometrical approach, with a tabulation of docility criteria for passive end-loading, ideal-transformer feedback, bilateral passive feedback, and arbitrary passive feedback. Includes consideration of a vacuum-tube amplifier problem as an illustrative example.

**SSB High Power Amplifier Design.** F. B. Gunter. *Tele-Tech*, June, 1956, pp. 108, 109, 154, 160. Development of a linear amplifier using modern components which results in simplification, reduction in design, and higher performance.

*Circuits & Components*

**Design of a Simple Linear Frequency Discriminator.** K. G. Fancourt and J. K. Skwirzynski. *Marconi Rev.*, 2nd Quarter, 1956, pp. 61–77. Description of a method for the design of a device consisting of two tuned circuits, with their parameters chosen to minimize the harmonic content of the resulting demodulated system, particularly second and third harmonics.

**Tuned Circuits Containing Negative Resistance.** Josef Cross. *J. Appl. Phys.*, June, 1956, pp. 603–607. USAF-supported qualitative analysis of the combination of a negative resistance and an unsuitable resonant circuit, with physical considerations, expressed in a jump condition, serving to connect different analyticity regions of the circuit differential equations.

*Communications*

**V.H.F. Communication by Ionospheric Scatter.** A. W. Cole. *Electronic Eng.*, June, 1956, pp. 230–235. 12 refs. Review of the characteristics of the method of propagation, with description of typical transmitters, receivers, and antenna systems.

*Delay Lines*

**Variable Delay Line Simulates Radar Targets.** S. A. Gitlin. *Electronics*, June, 1956, pp. 143–145. Development of a delay device which can vary the time delay of the frequency-modulated 5.5 mc. sine wave from 72 to 1,400 microsec.

*Electronic Tubes*

**The Design of High-Power Traveling-Wave Tubes.** M. Chodorow and E. J. Nalos. *Proc. IRE*, May, 1956, pp. 649–659. USAF-Navy-Army-supported experimental investigation of the problems involved in the design and operation of pulsed traveling-wave tubes operating at power levels of the order of a megawatt.

**Flicker Noise in Secondary Emission Tubes and Multiplier Phototubes.** R. C. Schwantes, H. J. Hannam, and A. van der Ziel. *J. Appl. Phys.*, June, 1956, pp. 573–577. Army-supported theoretical and experimental investigation of the effects of variations in work function of the cathode on the number of secondary electrons emitted per primary in the secondary emission process, and on the number of photoelectrons emitted per absorbed quantum in the photoemission process.

**Experiments with Gas-Filled Triodes.** J. A. Kok. *Appl. Sci. Res., Sect. B*, No. 6, 1956, pp. 445–453. Results describing the different types of electrical discharges dependent on determining parameters which include cathode emission; the spacing of cathode, grid, and anode; the diameter of the grid meshes; the grid and anode potentials; gas pressure; and the differential ionization function of the gas.

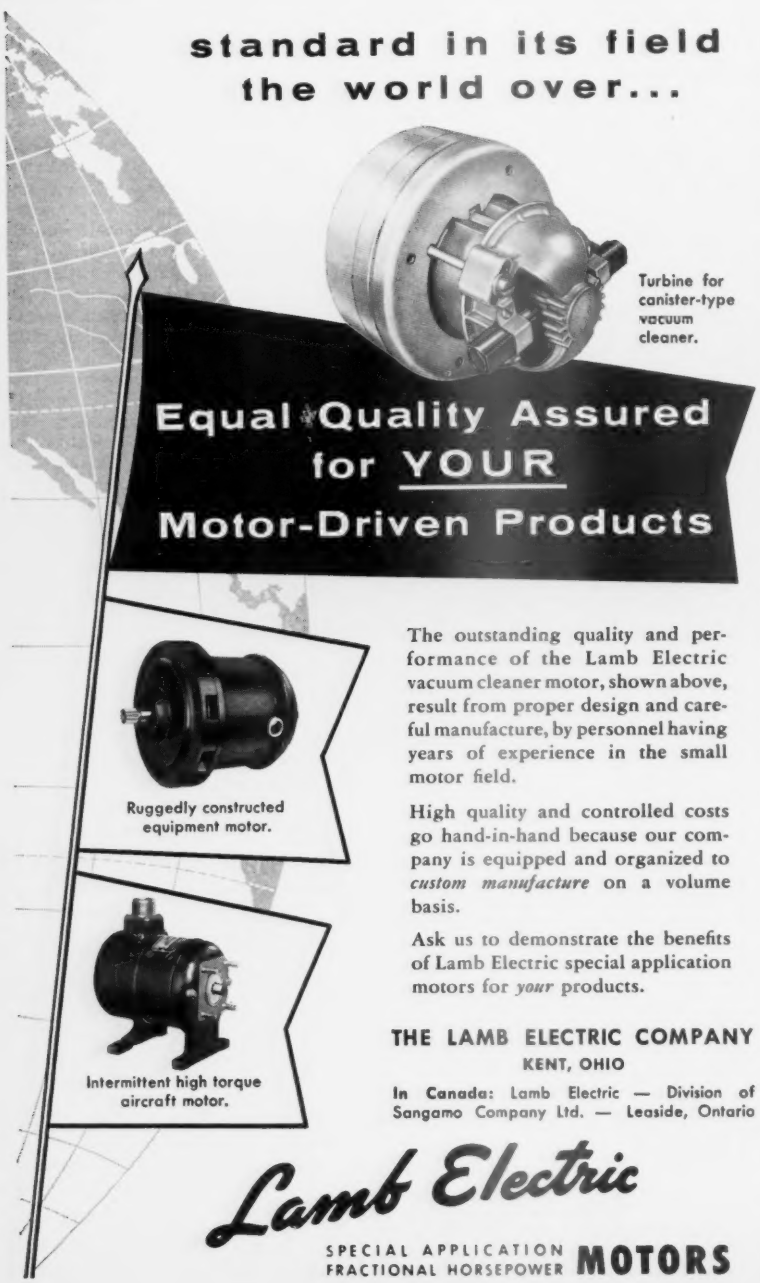
**Space Charge Effects in Dense, Velocity-Modulated Electron Beams.** M. Weinstein and H. M. von Foerster. *J. Appl. Phys.*, Apr., 1956, pp. 344–346. USAF-sponsored theoretical analysis to derive expressions of the variation of the current, and for the displacement and velocity of electrons at any point along the beam during one complete cycle of the UHF signal.

*Navigation Aids*

**Design of Height-Diversity UHF Direction Finders.** J. A. Fantoni and R. C. Benoit, Jr. *Tele-Tech*, June, 1956, pp. 90–92 ff. Development of ground-based direction-finding facility capable of operating in the UHF range in conjunction with radio transmissions from high-performance aircraft.

**A Servomechanism Approach to the Problem of Communication for Aircraft Control.** Stephen J. O'Neil. *IRE Trans., ANE Ser.*, June, 1956, pp. 55–66. 18 refs. Study of the traffic-handling

(*Continued on page 116*)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## ACOUSTICS, SOUND, & NOISE

AN INVESTIGATION OF THE NOISE PRODUCED BY A SUBSONIC AIR JET. J. H. Gerrard. J. Aero. Sci., Sept., 1956, pp. 855-866, 873. 15 refs. Measurements, over a wide frequency range and in 1/3 octave bands in this range, of the sound field of a 1-in. air jet issuing from a long pipe, with the mean Mach Number at the pipe orifice varying from 0.3 to 1.0, in order to determine the validity of the Lighthill predictions on aerodynamic sound. Examination of the dependence of the apparent position of the noise sources on frequency and jet speed, and of the dependence of noise intensity upon jet speed in terms of the power relation $\bar{p}^2 \propto M^n$. Results indicate that the apparent spread of the sources at low frequencies is due to the Doppler effect and that at a given jet speed there is a frequency at which the Mach Number ($M_c$) of convection of the sources, which is a function of frequency, is at a maximum. This maximum frequency increases with jet speed. Because the values of $M_c$ are comparable with unity, the Doppler effect must be considered when analyzing the sound field. The spectrum of the acoustic power output of the jet is found to be extremely flat, with the maximum power output lying at about 4 kc./sec. and being almost independent of jet speed. Further results indicate that the acoustic efficiency of the jet is very small and that the noise field is well represented, qualitatively, by the Lighthill theory.

## AERODYNAMICS

### Aerothermodynamics

DIFFUSION EFFECTS IN A BINARY ISOTHERMAL BOUNDARY LAYER. E.R.G. Eckert and P. J. Schneider. U. Minn. Inst. Tech. Dept. Mech. Eng. TR 5 (OSR TN 55-258), Nov., 1955. 15 pp. Evaluation of the mass-transfer cooling method. Similarity solutions are obtained for plane longitudinal flow over a flat porous plate with normal injection of a fluid whose variable properties are widely different from those of the main stream. Variation of properties with mixture temperature and concentration are evaluated from results of the molecular theory. Particular boundary-layer calculations are performed by the method of succesive approximations for hydrogen injection into an air boundary layer under isothermal conditions. Calculated skin-friction coefficients are compared with corresponding values for the case of constant-property diffusion.

TURBULENT-HEAT-TRANSFER MEASUREMENTS AT A MACH NUMBER OF 3.90. M. J. Brevoort. US, NACA TN 3734, July, 1956. 15 pp. Experimental investigation using an axially symmetric annular nozzle consisting of an inner, shaped center body and an outer cylindrical sleeve. Measurements taken along the outer sleeve give essentially flat-plate results that are free from wall interference and corner effects for M=3.90 and for a Reynolds Number range of $6.3 \times 10^5$ to $7.0 \times 10^7$. The heat-transfer-coefficient results are slightly higher than those obtained theoretically for M=4.0 and for a ratio of inside-surface temperature to free-stream temperature of 4.2. The temperature-recovery factors range from approximately 0.89 when $R=6.3 \times 10^5$ to approximately 0.86 when $R=7.0 \times 10^7$.

### Boundary Layer

SOME PROBLEMS IN BOUNDARY-LAYER TRANSITION. J. A. Steketee. UTIA Rep. 38, Apr., 1956. 105 pp. 46 refs. Theoretical investigation, using models which illustrate some aspects of the reality, to establish the existence of regions of turbulent flow clearly distinguished from, and surrounded by, laminar flow, and to determine the way in which these regions grow and are transported, in order to provide analytical support for the empirical facts forming the basis for the Emmons theory of boundary layer transition. Results indicate that: the Emmons formula for the fraction of the time during which a point in the transition region will be covered with turbulent

flow can be derived in a straightforward way, eliminating the need for the $\Upsilon(P P_0) d V$ functions; it is plausible that in the initial stages the turbulence is nonisotropic, since the energy equations illustrate that no energy exchange takes place between the main flow and the turbulence if the turbulence is isotropic; the three-dimensional viscous disturbance obtained is not unique; and that there is no obvious way of restricting the numerous arbitrary constants of the solutions. Results further indicate that the velocity gradient, rather than the viscosity, is the factor which distinguishes the flow in regions where turbulence originates from the flow in a free stream. This is particularly important in dealing with the turbulence as a perturbation.

AN EVALUATION OF FOUR EXPERIMENTAL METHODS FOR MEASURING MEAN PROPERTIES OF A SUPERSONIC TURBULENT BOUNDARY LAYER. G. J. Nothwang. US, NACA TN 3721, June, 1956. 34 pp. Analytical results of surveys made through a turbulent boundary layer on a flat plate, at one longitudinal station on the plate, by means of a pitot probe, an X-ray densitometer, and hot-wire and cold-wire probes, with tests conducted in an 8- by 8-in. supersonic nozzle at free-stream Mach Number of 3.03 and Reynolds Number of approximately 210,000 based on boundary layer thickness. The object of the analysis is to determine the reliability of the basic data and how well the actual distributions of properties in the boundary layer compare with those commonly assumed in semi-empirical and theoretical analyses. Results indicate that: the values of mean pitot pressure, density, and total temperature obtained from the pitot probe, X-ray densitometer, and cold-wire probe combine to produce consistent distributions of mean Mach Number, total temperature, and mass flow throughout the boundary layer; the hot-wire probe gives values of mean mass flow over the outer portion of the boundary layer higher than those shown by the other test methods, suggesting that caution should be used in interpreting hot-wire data to represent mean mass flows in turbulent supersonic boundary layers; the assumption of constat total temperature through the boundary layer yields negligible errors in displacement and momentum thicknesses, as do computations from pitot data and the same assumption with regard to velocity distribution; and the one-sixth power law agrees with the experimental velocity distribution within ±2%.

DÉCOLLEMENT LAMINAIRE EN DEUX DIMENSIONS; CONFRONTATION ENTRE THÉORIE ET EXPÉRIENCE. E. A. Eichelbrenner and H. Werlé. La Recherche Aéronautique, May-June, 1956, pp. 11-18. In French. Comparison of experimental results obtained from tests in the Chatillon hydrodynamic tunnel with calculations of the point of laminar separation and of the velocity profiles in the boundary layer located immediately downstream of the separation, obtained by using the Polhausen method. Results show an angle of separation approaching 90°, and the line of separation tends to become parallel to the direction of the flow to infinity. This indicates that the Polhausen hypotheses are a good approximation for the upstream and downstream cases, but cease to be valid in the immediate vicinity of the separation point.

ELEMENTARER EXISTENZBEWEIS FUR DIE GRENZSCHICHTSTRÖMUNG AN EINER KLASSE ROTIERENDER KÖRPER. Theo Geis. ZAMM, May-June, 1956, pp. 222-229. In German. Analysis of the problem of finding the boundary layer flow on bodies of revolution of a certain shape (rotating about their own axis in otherwise undisturbed fluid) in which the system of ordinary differential equations $F'' + cGF'' + 2G'(1 - F') = 0$; $G'' + cGG' - G'^2 + (1 - F')^2 = 0$ has to be solved with the boundary conditions $F'(0) = G(0) = G'(0) = 0$, $F'(\infty) = 1$, $G'(\infty) = 0$. Proof of the existence of at least one solution of the boundary value problem by generalization of an elementary method first used by Iglish.

## Control Surfaces

AN INVESTIGATION OF FORWARD-LOCATED FIXED SPOILERS AND DEFLECTORS AS GUST ALLEVIATORS ON AN UNSWEPT-WING MODEL. D. R. Croom, C. C. Shufflebarger, and J. K. Huffman. US, NACA TN 3705, June, 1956. 26 pp. Evaluation of forward-located fixed spoilers, deflectors, or a spoiler-deflector combination to determine their static longitudinal aerodynamic characteristics and gust alleviation capabilities. Results show that the lift-curve slopes are fairly linear and substantially reduced by the addition of either the spoiler or the deflector configuration. The slope, however, is nonlinear for the spoiler-deflector combination. Extending the deflectors necessitates only small changes in attitude and trim in order to maintain a given lift coefficient, whereas extending the spoiler or the spoiler-deflector combination requires large changes. Both the spoiler and the deflector configurations appear to be effective in reducing the normal acceleration in both an upgust and a downgust. A forward located fixed deflector appears to be an effective alleviator of gust loads on an unswept wing when turbulence is encountered because it reduces normal accelerations, aids in slowdown to rough-air speed, and requires only small trim changes.

## Fluid Mechanics & Aerodynamic Theory

PRELIMINARY LOW SPEED WIND TUNNEL TESTS ON FLAT PLATES AND AIR BRAKES: FLOW, VIBRATION AND BALANCE MEASUREMENTS. R. Fail, T. B. Owen, and R. C. W. Eyre. Gt. Brit., ARC CP 251, 1956. 45 pp. BIS, New York, $1.08. Includes flow measurements behind sharp-edged flat plates (a) at 90° for various shapes and (b) for a square plate over an incidence range, and lift, drag and pitching-moment increment measurements on a square plate mounted (c) on a long cylinder and (d) near the end of several shapes of rear fuselage. Results of (a) show a closed bubble about three plate sides long, with a constant pressure boundary up to the maximum diameter, followed by mixing. Measurements of velocity fluctuations taken for (b) show that a reg-

ular shedding of turbulent eddies, with which large random low-frequency fluctuations are associated, occurs for $\theta = 50^{\circ}$ and over, but stops at $40^{\circ}$. Velocity fluctuation measurements, at $70^{\circ}$ only, indicate a much reduced longitudinal unsteadiness for case (d). Comparative tests on a cascade brake demonstrate that no shedding occurs.

EXPERIMENTS ON TWO DIMENSIONAL BASE FLOW AT M = 2.4. L. Fuller and J. Reid. Gt. Brit., RAE Rep. Aero. 2569, Feb., 1956. 50 pp. Tests on a family of two-dimensional afterbodies to determine the effects of boattail angle and internal flow on the base pressure, afterbody pressure, and velocity distribution in the wake. Includes measurements of the affected parameters for each member of the family over a range of internal flows extending from zero flow to $\frac{\rho_j}{\rho_\infty} = 1.1$, measurement of the effect of internal flow on the plate pressure behind the base to provide further data on the base flow with the untapered afterbody, and schlieren photograps to supplement the pressure measurements in all cases. Results are analyzed and discussed theoretically and with regard to their practical applications.

PRELIMINARY REPORT ON A STUDY OF SEPARATED FLOWS IN SUPERSONIC AND SUBSONIC STREAMS. D. R. Chapman, D. M. Kuehn, and H. K. Larson. U.S., NACA RM A55L14, June 12, 1956. 15 pp. 10 refs. Results of theoretical and experimental investigations, with measurements for a variety of two-dimensional shapes and observation of the overall pressure rise to the separation pont and to the first peak pressure in flows where sizable separated regions exist. The location of transition relative to the reattachment and the separation conditions is taken into account. Models include forward and rearward facing steps; compression corners; curved surfaces to simulate the flow upstream of a spoiler control, behind a base or spoiler, over an inlet ramp or deflected flap, and over one side of a compressor blade, respectively; special models to produce leading-edge separation; and configurations to produce separation by reflecting a shock wave from a boundary layer. Wall static pressure distributions, surface oil-film observations, and high-speed motion picture studies were made for experiments at Mach Numbers between 0.4 and 3.3 and Reynolds Numbers, based on characteristic model length, between 4,000 and 4,000,000. It is concluded that the variable most important to a separated flow is the location of transition, as certain qualitative characteristics, such as Reynolds Number effects and flow steadiness, are the same for all cases when the various separated flows are studied according to the relative-transition location. The stability of a separated laminar mixing layer increases markedly as the speed increases over the range investigated.

TRANSPORT PROPERTIES FOR BINARY GAS MIXTURES. W. O. Carlson and P. J. Schneider. U. Minn. Inst. Tech. Dept. Mech. Eng. TR 7 (OSR TN 56-45), Jan., 1956. 46 pp. 14 refs. Review of various methods for calculating transport properties to select or develop the most rapid method of calculating these properties over a full range of mixture concentrations and a wide range of mixture temperatures. The properties discussed are the density, constant-pressure specific heat, viscosity, thermal conductivity, binary diffusion coefficient, and the thermal diffusion factor.

ON EQUATIONS OF MOTION FOR A COMPRESSIBLE VISCOUS GAS. E. V. Laitone. J. Aero. Sci., Sept., 1956, pp. 846-854. 20 refs. Evaluation of the Navier-Stokes equations, the higher order kinetic theory approximations, and the first-order dynamic equations of continuum mechanics, in terms of their usefulness in calculating compressible viscous flow. Includes comments and experimental observations on the effect of rigid body rotation. The theoretical reasons underlying the introduction of the bulk viscosity into the Navier-Stokes equations are discussed, and it is shown that these equations are better adapted for the necessary calculations when the Stokes relation is neglected, than are the higher order kinetic theory equations which do not include all the terms of the proper order because of the assumed form for the expansion of the distribution function. The main term that may be legitimately added to the Navier-Stokes equations is the Maxwell's effect of thermal transpiration.

THE FLOW PAST AN UNSWEPT- AND A SWEPT-WING-BODY COMBINATION AND THEIR EQUIVALENT BODIES OF REVOLUTION AT MACH NUMBERS NEAR 1.0. W. F. Lindsey. US, NACA TN 3703, June, 1956. 18 pp. Tests using the schlieren method of flow visualization to provide data for comparison. Results indicate that the flow past the equivalent body duplicates or closely approximates that past the wing-body combinations, and that this similarity diverges as the bump representing the wing area on the equivalent body departs from a slender bump or a small divergence.

A POTENTIAL FLOW MODEL FOR THE FLOW ABOUT A NACELLE WITH JET. Appendix A---A POTENTIAL FLOW MODEL FOR TWO DIMENSIONAL DUCT FLOW. Appendix B---THE TWO DIMENSIONAL DUCT AT INCIDENCE. Appendix C---THE AXI-SYMMETRIC DUCT IN POTENTIAL FLOW. A. H. Craven. Coll. of Aeronautics, Cranfield, Rep. 101, Mar., 1956. 54 pp. 13 refs. Results of theoretical investigation indicate that: the potential flow model for the jet flow from a nacelle is limited in its application by the method used in deriving it; the representation of a duct by a simple vortex distribution is only permissible when the duct is thin, when the difference in speeds of the jet and stream is small, and when the speeds are low; the thickness of the duct and wake leads to additional problems when the added complication of the jet flow is included; and the effects of temperature and density difference between the jet and the free stream must be taken into account.

INVESTIGATION AT SUPERSONIC SPEEDS OF THE VARIATION WITH REYNOLDS NUMBER AND MACH NUMBER OF THE TOTAL, BASE, AND

**SKIN-FRICTION DRAG OF SEVEN BOATTAIL BODIES OF REVOLUTION DESIGNED FOR MINIMUM WAVE DRAG.** A.F. Bromm, Jr., and J.M. Goodwin. US, NACA TN 3708, June, 1956. 20 pp. Experiments in the Langley 9 in. supersonic tunnel covering a Reynolds Number range from approximately $1.0 \times 10^6$ to $10.0 \times 10^6$ at Mach Numbers of 1.62, 1.93, and 2.41. Results show that the base drag and, in general, the total drag increase with increasing values of the ratio of base area to maximum area $B/S_{max}$. The laminar skin-friction drag is in agreement with the theoretical predictions and the simple Blasius incompressible theory gives a satisfactory prediction within the test Mach Number range. Except for values of $B/S_{max}$ near 1, the Reynolds Number of transition increases with increasing Mach Number, and when this ratio approaches 1, the variation reverses.

**L'ÉCOULEMENT SUPERSONIQUE AUTOUR D'UNE AILE A DISQUE AXIAL.** Elie Carafoli and Béatrice Horovitz. Rev. Méc. Appl., No. 1, 1956, pp. 7-33. In French. Study of the supersonic flow around an airfoil equipped with an axial disc. Application of the theory of conical flows and determination of the axial component for different cases, with a discussion of other practical applications.

**K TEORII TEL MALOGO UDLINENIIA.** M. N. Kogan. Prikl. Mat. i Mekh., 1956, pp. 87-94. In Russian. Analysis of the use of the theory of conformal transformations in solving three-dimensional problems of a supersonic flow past airfoils. Discussion of errors inherent in conformal transformations; estimation of the error caused by the linearization of equations for velocity potential, taking into account the example of a flow past a circular cone; comparison with the theory of thin airfoils; and consideration of the supersonic flow past a triangular wing. A comparison with the thin wing theory shows that the formula for the potential of a turbulent supersonic flow contains a second term. Includes a discussion of the apparent discrepancy between the solutions for an airfoil and a circular cone.

**THE ROTATIONAL FIELD BEHIND A CURVED SHOCK WAVE CALCULATED BY THE METHOD OF FLUX ANALYSIS.** Shigeo Uchida and Michiru Yasuhara. J. Aero. Sci., Sept., 1956, pp. 830-845. 34 refs. Description of the method which makes use of streamline coordinates. Includes a calculated example of supersonic flow around a circular cylinder having a detached bow shock wave, and an asymptotic approximate solution of nonviscous supersonic or hypersonic flow along a flat plate. A relation between velocity and flow patterns under the known distribution of entropy is derived from the integration of the vorticity equation along the curvilinear coordinate perpendicular to the streamlines. The stream function can be calculated and the flow patterns corrected by integrating the formula by the first assumed pattern of flow and entropy, and successive procedures permit the determination of the flow field behind a curved shock wave.

**SUR LA TURBULENCE SPATIALEMENT HOMOGÈNE D'UN FLUIDE COMPRESSIBLE.** M. Z. Krzywoblocki. France, Min de l'Air PST 314, 1956. 54 pp. 10 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 650. In French. Generalization of the Kampé theory, taking into account the von Kármán, Kolmogoroff, Heisenberg, and Onsager theories. Derivation of fundamentals of the existence of scalars and of correlation and spectral tensors in the spatially homogeneous turbulence of a compressible fluid. Derivation of the fundamental equation of kinetic energy of the spectrum is based on the hypothesis that the functions of velocity, volume, and temperature satisfy the Navier-Stokes equations. Includes a discussion of the shape of the particular spectral tensor of the spatially homogeneous turbulence in compressible fluid.

## Internal Flow

**STALL PROPAGATION IN AXIAL-FLOW COMPRESSORS. Appendix A- CALCULATION OF CASCADE DISCHARGE COEFFICIENT FOR REAL CASCADE. Appendix B - STALL PROPAGATION VELOCITY IN POLAR COORDINATES. Appendix C - STALL PROPAGATION VELOCITY WITH FLOW INTO A CONTINUUM.** A.H. Stenning, A.R. Kriebel, and S.R. Montgomery. US, NACA TN 3580, June, 1956. 83 pp. 11 refs. Derivation of a theory, based on the assumption that the flow behind the cascade consists of free jets discharging into a constant pressure region. The effects of finite blade chord and of the boundary-layer response to changes in angle of attack are taken into account and the theory is valid for small perturbations in velocity about a mean flow condition with finite pressure rise across the cascade, provided that the pressure fluctuations downstream of the cascade are much smaller than those upstream. Analytical results indicate that the wave length of the stall cells at the beginning of rotating stall is dependent on the boundary-layer time delay. The values obtained for the stall propagation velocities agree within 25% over a wide range of wave lengths with experimental results on both stationary circular cascade and the single-stage compressor. It is also shown that, when the flow downstream of the cascade is treated as a continuum, the solution for the stall propagation velocity applies to the case of large waves with a small pressure rise across the cascade, for which the predicted stall propagation velocities are much lower than those obtained experimentally.

**TECHENIE VIAZKOGO GAZA MEZHDU DVUMIA DVIZHUSHCHIMISIA PARALLEL'NYMI TSILINDRICHESKIMI POVERKHNOSTIAMI PROIZVOL'NOI FORMI.** E. L. Blokh. Prikl. Mat. i Mekh., 1956, pp. 116-119. In Russian. Study of the flow of viscous gas between two parallel cylindrical surfaces of arbitrary form. The motion of gas is assumed to be caused by the rotation of the surfaces of which the inner is taken to be stationary. It is shown that for this type of motion, the ratio of the forces of resistance for viscous gas and viscous fluid is not affected by the configuration of the cross section of cylinders. Two numerical

examples considered include the flow of viscous gas between two parallel planes and the flow between two co-focal elliptical cylinders.

ESSAIS DE DEUX GRILLES D'AUBES DE COMPRESSEURS. Robert Legendre. La Recherche Aéronautique, May-June, 1956, pp. 3-10. 13 refs. In French. Results of low-speed wind-tunnel experiments on compressor blades. The calculation of blade grids is a mathematical procedure useful for controlling the velocity distribution on which the formation of boundary layers depends, and permits the prediction of the direction of the exhaust velocity and the pressure distribution. The tests provide information regarding losses and the coefficient of compression. The influence of the relative motion of the blading on the formation of boundary layers is taken into account.

ENTRY OF CONDUCTING AND NON-CONDUCTING FLUIDS IN PIPES. J. A. Shercliff. Proc. Cambridge Philos. Soc., July, 1956, pp. 573-583. Linearization, by means of a Rayleigh approximation adapted for cases involving a pressure gradient, of the problem of estimating the entry length over which the laminar motion of an electrically conducting, viscous fluid in a pipe under a transverse field adjusts to a steady state from some initial state. Solutions are found in the cases of motion between infinite parallel planes and in rectangular pipes when magnetic effects occur, and for parallel planes and rectangular and circular pipes in the absence of magnetic effects.

THEORETICAL INVESTIGATION OF THE INFLUENCE OF VISCOUS FRICTION ON A PLANE WAVE OF FINITE AMPLITUDE IN A COMPRESSIBLE FLUID. J. A. Owczarek. Quart. J. Mech. & Appl. Math., June, 1956, pp. 143-163. Application of the method of characteristics to the problem, with derivation of equations suitable for step-by-step solutions. Extension of the method permits the deduction of analytical expressions, subject to numerical integration, for the change of parameters of the state of a wave due to friction. Results indicate an approximate procedure for the solution.

ANALYTIC DETERMINATION OF TWO-DIMENSIONAL SUPERSONIC NOZZLE CONTOURS HAVING CONTINUOUS CURVATURE. J. C. Sivells. USAF AEDC TR 56-11, July, 1956. 29 pp. Methods of determining coodinates for perfect-fluid contours downstream of the inflection point in a supersonic nozzle. Two approaches are used, the first - numerical integration along each characteristic, as accurate as desired and depending upon the number of intervals used in the integration; the second - a weighting factor to perform the integration, saving considerable time by using values only at each limit of the integration. It is found to be as accurate as the first approach, and the resulting equations can be differentiated to obtain an analytic expression for the second derivative.

LE TRACE DU PROFIL D'UN COLLECTEUR POUR SOUFFLERIE AERODYNAMIQUE. M. V. Sisojev. Tech. et Sci. Aéronautiques, No. 2, 1956, pp. 100-104. In French. Development of a method based on analytic principles for calculating the profile of a contraction cone used in a closed-circuit, aerodynamic wind tunnel. The problem is treated in such a way as to obtain a graphical solution with minimum effort. The proposed method is applicable to the case of an incompressible ideal fluid and, through a further development, offers the possibility of introducing corrections for the compressible case.

SOME TESTS ON THE SPREAD OF VELOCITY IN A COLD JET DISCHARGING WITH EXCESS PRESSURE FROM A SONIC EXIT INTO STILL AIR. J. Seddon and L. Haverty. Gt. Brit., ARC CP 246, 1956. 15 pp. BIS, New York, $0.45. Examination of the spread of the half-velocity circle over the range 40 to 200 diameters from the exit, with jet pressure ratios from 0.479 to 0.042, corresponding to isentropic Mach Numbers of 1.08 --2.72. Results indicate that rates of spread are not greatly different from those for a subsonic jet, but that the effective exit of an underexpanded jet is displaced downstream of the actual exit.

## Wings & Airfoils

A METHOD FOR CALCULATING THE PRESSURE DISTRIBUTION OVER JET-FLAPPED WINGS. D. Kuchemann. Gt. Brit., RAE Rep. Aero. 2573, May, 1956. 38 pp. 18 refs. Analysis based on Spence calculation of circulation and chordwise loading of a jet flap system to find the pressure distribution when the external lift force and the jet momentum are known. Analysis includes the effects of non-zero thickness and camber, and extends to both wings of finite aspect ratio and to swept wings. Only incompressible inviscid flow and forces on the external surfaces are considered, leaving out the flow phenomena near the exit nozzle. Results show that a saddleback, chordwise loading is typical for an airfoil with jets and is the basic reason for the aerodynamic advantage of the jet-flap system.

PRELIMINARY WIND-TUNNEL TESTS OF TRIANGULAR AND RECTANGULAR WINGS IN STEADY ROLL AT MACH NUMBERS OF 1.62 AND 1.92. C. E. Brown and H. S. Heinke, Jr. US, NACA TN 3740, June, 1956. 36 pp. Experimental investigation for determining the damping-in-roll coefficients for a series of thin triangular plan-form and two rectangular wings. The triangular wing series consisted of nine wings of vertex angles such that a range of leading edge positions ahead of and behind the Mach cone was obtained at Mach Numbers 1.62 and 1.92. The rectangular wings had aspect ratios of 2.00 and 2.73. Results indicate that damping in roll of the rectangular wings was very close to that predicted by linear theory for isolated wings. The triangular wings gave results approximately 10% below those predicted when the wing leading edges were well ahead of or behind the Mach cone. Somewhat greater reductions in damping coefficients from the linear theory were found when the leading edges were in the vicinity of the Mach cone.

**THEORETICAL WAVE DRAG OF SHROUDED AIRFOILS AND BODIES.** P. F. Byrd. US, NACA TN 3718, June, 1956. 40 pp. 10 refs. Analysis of symmetrical airfoils shrouded with flat plates, and bodies of revolution shrouded with a cylindrical shell to determine the wave drag. The detrimental effect of the additional friction drag due to the shroud is neglected. Linearized theory is assumed, and the operational methods apply Laplace transforms. Results obtained hold for a Mach Number range dependent on the geometry of the configuration. Expressions are also given for determining a class of body shapes for which the wave drag is theoretically zero, and for determining the pressure coefficient of a shrouded body.

**EXPERIMENTAL RESEARCH ON WING SECTIONS AT HIGH SPEEDS.** Masatada Tada. J. Japan Soc. Aero. Eng., June, 1956, pp. 5-10. In Japanese. Investigation of the relation between scale and compressibility effects by making drag and pressure distribution tests on spheres, cylinders, and other shapes. Characteristics of wing profiles at high speeds are also compared.

**THE EFFECT OF WING PLAN FORM ON THE DOWNWASH BEHIND WINGS.** Akira Mitsuyasu. J. Japan Soc. Aero. Eng., June, 1956, pp. 1-5. In Japanese. Calculation of theoretical downwash angles and their comparison with experimental results. The results indicate that for both the theoretical and experimental cases there is a decrease in downwash with an increase in sweep, but that the downwash derivative behind a sweptback wing increases with an increase in the angle of attack when under the effect of leading-edge separation.

**THE LIFT ON A THIN AEROFOIL WITH A BLOWN FLAP.** D. A. Spence. Gt. Brit., RAE TN Aero. 2450, May, 1956. 17 pp. Analysis of attached flow on a thin airfoil for the cases of hinged flap without a jet and hinged flap with a tangential jet. Results are presented for a range of jet flux-momentum coefficients ($C_J$) and a number of flap-chord ratios (E). These indicate that for a given $C_J$ and deflection, higher coefficients of lift are obtained with larger flaps, and for a given $C_L$ and deflection, the larger the flap, the smaller the $C_J$ is necessary.

**FLIGHT TESTS AT SUPERSONIC SPEEDS TO DETERMINE THE EFFECT OF TAPER ON THE ZERO-LIFT DRAG OF SWEPTBACK LOW-ASPECT RATIO WINGS.** M. Pittel. US, NACA TN 3697, June, 1956. 20 pp. Derivation of experimental data, using rocket-powered-modal technique, in the Mach Number range of 1.0 to 1.8, with theoretical comparisons for the range above $M = 1.2$. Results indicate that: wings with more taper give higher drag coefficients from $M \approx 1.0$ to $M \approx 1.3$, with lower values of drag coefficient above $M \approx 1.3$; wings of aspect ratio 4 have less drag below $M \approx 1.2$, and greater drag above $M \approx 1.2$, than those of aspect ratio 2. Theoretical and experimental results agree qualitatively as to the effects of taper and aspect ratio.

**TRAÎNÉE D'AILES DELTA DOUBLEMENT-CONIQUES À PENTE VARIABLE, EN RÉGIME SUPERSONIQUE.** E. Carafoli and M. Ionescu. Rev. Méc. Appl., No. 1, 1956, pp. 35-55. In French. Development of a method for calculating the drag of doubly conical delta wings having varied slope. The profile of the wing permits the assimilation of the flow around it in two distinct motions. Simple calculations lead to the detailed expression of the coefficient of total drag. As an illustrative application the calculation of the drag of a wing, whose slope varies linearly along the span, is presented.

**PORTANCE D'UNE PLAQUE PLANE DÉCÉLÉRÉE FRANCHISSANT LA VITESSE DU SON.** A. von Baranoff. La Recherche Aéronautique, May-June, 1956, pp. 19-25. In French. Study of the linearized problem of a plane surface in decelerated motion passing the speed of sound indicates that the preliminary calculation of the deflection zone, encountered during the supersonic phase, permits treating the subsonic phase by using the Evvard-Ward method. The method of calculating the zone deflection is indicated. The results of a numerical application, giving the gradient of the lift coefficient as function of Mach Number, are given for a particular deceleration value.

**ASPECT RATIO INFLUENCE AT HIGH SUBSONIC SPEEDS.** G. F. Anderson. J. Aero. Sci., Sept., 1956, pp. 874-878. OSR-sponsored investigation describing a method to predict the velocity induced by the thickness of a thin finite wing using linearized subsonic compressible flow theory, and assuming the finite wing to be part of an infinite wing, the rest of which is removed from the flow. The velocity at any point on the infinite wing is less by the velocity induced by the removed portion. If the part removed is relatively far away from the point on the wing for which the induced velocity is being calculated, linearized subsonic compressible flow theory is applicable, and using such a scheme a correction to the free-stream velocity is derived from the averaged difference in the induced velocity over the area of the finite wing. At this increased free-stream velocity the finite wing should have approximately the same pressure distribution as the infinite wing at the uncorrected free-stream velocity.

**THEORETISCHE UND EXPERIMENTELLE UNTERSUCHUNGEN AN DELTAFLÜGELN MIT KLAPPEN BEI INKOMPRESSIBLER STRÖMUNG.** Erich Truckenbrodt and K.-H. Gronau. ZFW, July, 1956, pp. 236-246. In German. Theoretical computations of the lift distribution at various flap configurations and flap deflections in incompressible flow for five delta wings of various aspect ratios, with simultaneous wind-tunnel measurements in two cases.

**THE DESIGN OF SWEPT WING PLANFORMS TO HAVE SPECIFIED DISTRIBUTIONS OF LOCAL LIFT COEFFICIENT.** G.G. Brebner. ZFW, July, 1956, pp. 249-253. Systematic calculations of the form of spanwise distribution of local lift coefficient $C_{Ll}$, as one cause of the high suctions formed over

the outer part of sweptback wings which result in the flow separation associated with the well-known instability of such wings. Results indicate that for a given angle of sweep and aspect ratio a wing planform can be assigned to give any specified spanwise $C_{Ll}$ distribution without using camber and twist. Consideration of the case of planforms having constant $C_{Ll}$ for several aspect ratios and sweep arrangements indicates that there is an upper limit to the aspect ratio for which constant $C_{Ll}$ is possible for a given angle of sweepback.

WIND TUNNEL TESTS ON A SLENDER DELTA WING AT HIGH INCIDENCE. P. T. Fink. ZFW, July, 1956, pp. 247-249. Experiments to investigate the vortex separation observed on bodies of revolution at incidence, using a thin, sharp-edged plate of triangular planform as a model. Results are compared to those predicted in theories based on that of Legendre. Includes the determination of the surface static pressure along seven rays passing through the apex of the wing in order to ascertain whether there are stations at which the pressure distribution may be taken to be two-dimensional; plotting of the values of the static pressure coefficient $c_p$ as functions of the dimensionless spanwise coordinate y/a for the angles of incidence $a=5^o$, $15^o$, and $25^o$; determination of the local normal force coefficients by integration of the pressure distributions; and determination of contours of constant total head over the suction side of the plate for $a=5^o$ and $15^o$, by transversing with a small pitot tube housed in a vented shield of 1.6 mm. diameter.

## AEROELASTICITY

AEROELASTIC PROBLEMS IN CONNECTION WITH HIGH-SPEED FLIGHT. E. G. Broadbent. J. RAeS, July, 1956, pp. 459-475. 20 refs. Review of the developments in the field of aeroelasticity during the past ten years, with emphasis on the problems induced by increasing Mach Number. Problems considered include the use of thinner airfoils which require a greater stiffness, and the uncertainty of the calculations for flutter coeffi - cients. Analysis covers aileron reversal, divergence, longitudinal control and stability, buffeting, effects of kinetic heating, and flutter. Wing flutter is discussed taking into account Mach Number effects, sweepback, body freedoms, and external stores. Tail flutter is discussed in terms of flexure-torsion flutter and fuselage flexibility. Some experiments are described and their importance in flutter work is evaluated.

AERODYNAMIC DERIVATIVES FOR TWO CROPPED DELTA WINGS AND ONE ARROWHEAD WING OSCILLATING IN DISTORTION MODES. D. L. Woodcock. Gt. Brit., RAE Rep. Struc. 201, Apr., 1956. 69 pp. Calculation of aerodynamic derivatives for three particular planforms oscillating with symmetric distortion modes in incompressible flow. The planforms are two cropped delta wings with taper ratios 1/7, and aspect ratios of 3 and 1.2 respectively. The third planform is an arrowhead wing of aspect ratio 1.32, taper ratio 7/18, and an angle of sweep of $63.4^o$ at the quarter chord. Results are based on Lehrian's work and have been obtained from the values of the matrices of the downwash velocities at the collocation points induced by the assumed doublet distribution function.

EXPERIMENTAL MEASUREMENTS OF FORCES AND MOMENTS ON A TWO-DIMENSIONAL OSCILLATING WING AT SUBSONIC SPEEDS. Appendix A - DETERMINATION OF THE INPHASE MOMENT AND THE CENTER-OF-PRESSURE SHIFT. Appendix B - DYNAMIC MAGNIFICATION OF LIFT FORCE. S.A. Clevenson and Edward Widmayer, Jr. US, NACA TN 3686, June, 1956. 28 pp. Results of wind-tunnel tests, including a few data in the transonic region and a description of an experimental method applicable to the transonic region. A 14-channel recording oscillograph is used to record and correlate data, with respect to time, regarding the motion of the wing in the tunnel and its reaction to the flowing gas and the supplied power necessary to maintain the oscillation. Good agreement exists between experimental results and those obtained theoretically by Dietze for the magnitude of the oscillating lift vector and for the coefficients in phase with the wing displacement.

LIFT AND MOMENT COEFFICIENTS FOR AN OSCILLATING RECTANGULAR WING-AILERON CONFIGURATION IN SUPERSONIC FLOW. Appendix A - COEFFICIENTS ASSOCIATED WITH WING MOTION. J. H. Berman. US, NACA TN 3644, July, 1956. 46 pp. 13 refs. Analysis using the linearized theory for compressible unsteady flow to treat the problem of a partial-span rectangular control surface, hinged at its leading edge and mounted on a rectangular wing oscillating in supersonic flow. The motions of the wing-aileron configuration are assumed to consist of vertical translation, pitching, and aileron rotation. The velocity potentials for this configuration are derived as power series in terms of a frequency parameter to the fifth power of the frequency of oscillation. From these potentials closed expressions for section force and moment coefficients at any spanwise location are derived.

METHODS FOR CALCULATING PRESSURE DISTRIBUTIONS ON OSCILLATING WINGS OF DELTA TYPE AT SUPERSONIC AND TRANSONIC SPEEDS. F. Hjelte. Stockholm, KTH AERO TN 39, 1956. 29 pp. 16 refs. Description of two procedures using the linearized theory. The first method is based on slender body theory and intended for small aspect ratio wings and low frequencies, and the second is an approximation for high frequencies. Both methods, which are valid for transonic as well as supersonic speeds and are based on Laplace transformations, are applied to some simple cases and compared with other methods.

THE FLUTTER OF A TWO-DIMENSIONAL BUCKLED PLATE WITH CLAMPED EDGES IN A SUPERSONIC FLOW. J. G. Eisley. GALCIT OSR TN 56-296, July, 1956. 40 pp. Theoreti-

cal and experimental investigation in which the theoretical work consists of a description of the flutter mode by a series expansion of functions which satisfy the boundary conditions for clamped edges. Quasi-steady linearized aerodynamics are used, and large deflections of the plate are considered. Included are numerical calculations which take into account only the first two terms of the series expansion. The experimental work involves wind-tunnel tests to check the validity of the theoretical assumptions and results and to provide insight into the panel-flutter process for use in future studies.

THE EFFECT OF WING TORSION ON AILERON-TAB FLUTTER. H. Hall. Gt. Brit., RAE Rep. Struc.203, Apr., 1956. 31 pp. Derivation of criteria for the prevention of wing torsion - aileron-tab flutter from results of calculations based on the assumption of an idealized ternary type spring-tab system having degrees of freedom in wing pitch, rotation of the control surface, and rotation of the tab. Includes comparison of results with those obtained by Wittmeyer and Templeton. In the present analysis the pitching degree of freedom is spring restrained and is intended to represent wing torsion, and the tab is restrained as a trim tab or pure aerodynamic servo tab. Values of aileron and tab natural frequency relative to wing torsional frequency, and specific tab underbalancing combined with static aileron balance are given as criteria for flutter prevention.

FLUTTER CALCULATIONS ON A RUDDER WITH TRAILING-EDGE SPOILER. Ll. T. Niblett. Gt. Brit., RAE Rep. Struc.202, May, 1956. 13 pp. Calculations of flutter on two different spoiler systems and comparison with flight tests. The first system considers two degrees of freedom and rudder and spoiler rotation, while in the second system a third degree of freedom, the rudder torsion, is also taken into account. Also in the second system a quaternary calculation including a fin flexural mode is made to check whether an overmassbalanced spoiler would give rise to flutter. The results show that the theoretical flutter speeds agree with the flight tests, but the flutter frequency does not. The quaternary calculation shows that the flutter, in which both the main surface and the main control-surface play necessary parts, is possible when the spoiler is overmassbalanced.

## AIR TRANSPORTATION

ECONOMICS OF ROCKET-PROPELLED AIRPLANES. I. Robert Cornog. Aero. Eng. Rev., Sept.,1956, pp. 30-36, 71. Analysis of the cost factors of a rocket-propelled transport aircraft. Methods maximizing gross income such as operating all equipment as much as possible and flying at high speed are included. An optimum flight program is outlined, taking into account launching technique and momentum gliding. The direct operational costs are broken down into six categories, and a comparison is made between present and future cost in rocket transportation. In the rocket aircraft fuel cost will account for about 80% of the total. Velocity requirements, propellant consumption, and costs of different fuels are discussed.

## AIRPLANE DESIGN

### Landing Gear

ON LANDING GEAR STRESSES. A. Gentric. (Docaero No. 25, Jan., 1954, pp. 17-38.) US, NACA TM 1422, July, 1956. 45 pp. Translation. Investigation of vibratory phenomena in landing gear. Descriptions are given of two test installations, a toboggan and a vertical drop test machine. The analysis takes into account tangential forces applied to landing gears, the inflation pressure of the tires, the sliding velocity, the nature of rubber in the tire, and the characteristics of the ground. Uncertainty in the determination of the friction coefficient owing to the many parameters involved is pointed out. Longitudinal oscillations are discussed, and possible solutions are presented. Examples of fatigue failure from longitudinal oscillations are also examined.

## COMPUTERS

THE SIMULATION OF MECHANICAL THRESHOLD. M. Squires. Gt. Brit., RAE TN G.W.403, Mar., 1956. 33 pp. Analysis of methods to produce electronic analogs for the threshold behavior found in some mechanisms. This behavior is characterized by a failure to develop relative motion between rubbing surfaces unless the applied tangential force exceeds some critical value; the common occurrence of a region of bistable operation due to reduction in the coefficient of friction with relative velocity; and a range of velocities which cannot be stably maintained. The first method is to obtain a rough analog of threshold behavior, omitting finer details in the interest of simplicity. A preferred simulator is then examined which gives a more complete analog, including bistable behavior and other forms of nonlinear force-velocity relationships. Finally an intermediate form of simulator is proposed in which bistable behavior is reproduced in a relatively crude manner, but is sufficient when the relative velocities of interest are not too small.

## ELECTRONICS

### Telemetry

AN INVESTIGATION INTO THE TRANSMISSION OF DATA OVER A TELEPRINTER LINK. Gt. Brit. RAE TN TD 2, Jan., 1956. 10 pp. Evaluation of data transmission over a teleprinting link to feed data from the test station to the computer for tracking a missile in flight, performed for a period of three months showed an accumulation of error induced by interference in the line and concluded that present continuous tape method of recording should be replaced by a system of direct transmission between Hollerith cards.

## FLIGHT TESTING

COMPARISON OF SEVERAL METHODS FOR OBTAINING THE TIME RESPONSE OF LINEAR SYSTEMS TO EITHER A UNIT IMPULSE OR ARBITRARY INPUT FROM FREQUENCY-RESPONSE DATA. J. J. Donegan and C. R. Huss. US, NACA TN 3701, July, 1956. 39 pp. Analysis of methods for converting information contained in a frequency response to the time phase in the form of a response to a unit impulse. Discussion includes inverse Laplace transform, Fourier, Schumacher, and P-transform methods. Comparisons indicate that all methods give good accuracy when applied to a second-order system; however, some of them, when applied to higher order systems, require excessive computing time to obtain the same degree of accuracy. The inverse Laplace transform methods are found to be the most useful for higher order systems. Examples are given for the use of these methods as flight-data-analysis techniques in predicting loads and motions of a flexible aircraft when the frequency response is known.

## FUELS

A STUDY OF INCORPORATION OF HIGH ENERGY SUBSTANCES IN CONVENTIONAL TYPE FUEL MATERIALS BY PHYSICAL INCLUSION. D. Horvitz, F. R. Benson, I. M. Roberts, and H. W. Weber, Jr. Metalectro TR (AFOSR TR 56-17), Apr., 1956. 34 pp. 17 refs. Investigation of methods to incorporate hydrogen or other high energy substances into fuel materials of conventional thermochemical values by a process of physical inclusion. Pressure methods are used to induce hydrogen molecules in the voids between the molecules (intermolecular inclusion), or within the molecule itself (intramolecular inclusion). Results show that attempts to include more than a single molecule of gas within an intramolecular void causes a rupture of the bonds holding the molecules together owing to the high internal pressure required.

## INSTRUMENTS

### Timing Devices

IMPROVED EQUIPMENT FOR TIMING WORLD AIRSPEED RECORDS AT HIGH ALTITUDE. N. E. G. Hill and W. Goldsmith. Gt. Brit. RAE Rep. Instn. 6, Apr., 1956. 35 pp. Development of timing equipment for use under F.A.I. rules. A camera and chronometer were especially designed and are described. Further includes descriptions of the technique of setting up, calibrating, and using the equipment; and the monitoring of the airplanes height during a speed record attempt. Analysis of random errors expected in the distance and time measurements indicates that determination of speed with a margin of error of one in 2000 should be possible at a height of 40,000 ft.

## MACHINE ELEMENTS

### Bearings

K TEORII SFERICHESKOGO PODSHIPNIKA. L. G. Loitsianskii. Prikl. Mat. i Mekh., 1956, pp. 133-135. In Russian. Derivation of a solution for the problem of motion of an incompressible viscous liquid between two spherical surfaces. The process is based on a precise integration of Reynolds equation and uses the partial integral of the equation obtained by Wannier. It is shown that the expressions for the main vector and the main moment of the reaction of the liquid have the same form as in the approximate solution of the problem.

## MATERIALS

TENSILE AND TENSILE FATIGUE PROPERTIES OF TRANSPARENT ENCLOSURE ATTACHMENTS FOR AIRCRAFT. E. Holm, W. Yamaguchi, M. E. Latham, and J. G. Stansbury. USAF WADC TR 54-396, July, 1954. 71 pp. Investigation of edge attachments for transparent aircraft enclosures. Sixteen types, ten of laminated and six of monolithic material, are tested for tensile strength at room temperature and at -65°F, and for tensile-fatigue at room temperature. Results indicate that the synthetic, fiber laminated materials are superior to glass cloth laminated materials for attaching edges where the enclosure may be loaded in bearing on the laminated edge. Tensile-fatigue properties improve with low-modulus attaching edges, and conversely static tensile properties increase with high-modulus attaching edges.

AIRCRAFT ARMAMENT EQUIPMENT. R. E. Kemelhor. Aero. Eng. Rev., Sept., 1956, pp. 48-53. Discussion of the metallurgical and material problems involved in the design, development, and manufacture of aircraft armament, with emphasis on the need for a high-strength, corrosion-resistant stainless steel material for use in bombing systems. Includes data on other materials used in aircraft armament mechanisms. Results of consideration indicate the need for a stainless steel type of material applicable for hook-type components with the following characteristics: an ultimate tensile strength of 200,000 psi min., and a yield tensile strength of 160,000 psi min.; Rockwell C-45 min. hardness on lug-bearing surface to prevent brinelling and galling; high toughness for both static and dynamic fatigue; the ability to sustain a static load of 150,000 psi min. indefinitely; sufficient corrosion resistance to obviate the need for additional coatings or platings; avoidance of problems now encountered in stainless steel, such as intergranular and atmospheric corrosion and pitting; consistency of materials during heat-treating and general processing; and ease of machining.

POISSON'S RATIOS AND VOLUME CHANGES FOR PLASTICALLY ORTHOTROPIC MATERIAL. E. Z. Stowell and R. A. Pride. US, NACA TN 3736, Aug., 1956. 28 pp. Measurements of Poisson's ratios in three orthogonal directions on aluminum-alloy blocks in compression and on stainless-steel sheet in both tension and compression, resulting in a method to correlate the measured individual values of the Poisson ratios and the stress-strain curves for the material. Results of measurements indicate no permanent plastic change

in volume within the accuracy of observation. The described method must make allowance for the difference in the stress-strain curves in tension and compression since this difference is accompanied by significant changes in the Poisson ratios wherever it appears.

## MATHEMATICS

NEW METHODS FOR SOLVING BOUNDARY VALUE PROBLEMS. Stefan Bergman. ZAMM, May-June, 1956, pp. 182-191. 33 refs. ONR-supported analysis to derive a procedure for using a method of operators in generating sets of solutions of linear partial differential equations with two and, in some cases, three variables. The method constitutes a generalization of the "take the real part" procedure. Applications to the theory of compressible fluids and for solving boundary layer and eigenvalue problems are indicated.

BOUNDEDNESS AND PERIODICITY OF SOLUTIONS OF THE GENERALIZED LIENARD EQUATION. W. R. Utz. Mo. U., MRG Rep. 6(AFOSR TN 56-282), June, 1956. 29 pp. 33 refs. Includes a discussion of boundedness theorems for certain special cases of the equation and presentation of theorems concerning the behavior of solutions for large values of t in cases where boundedness can not be inferred. Sufficient conditions are given for the existence of an infinity of periodic solutions when $\epsilon(t) \equiv 0$.

A METHOD FOR THE NUMERICAL EVALUATION OF AN INTEGRAL. Appendix---DERIVATION OF INTEGRATION FORMULA. T. Nonweiler. Coll. of Aeronautics, Cranfield, Rep. 100, Mar., 1956. 24 pp. Development of a method for an integral occurring in the expression for the wave drag of slender bodies. Formulas and data are presented for the numerical evaluation of the double integral where numerical values for the weighting coefficients and the lattice points are given. The method depends essentially on the representation of the function $F(x, y)$ in terms of a finite double Fourier series which can be shown to be equivalent to its expression as a polynomial in x and y divided by the square root of xy (1-y). The quadrature formulas developed are analyzed for a particular example in which the function F is a constant over the range of integration and $F(x, y)$ lacks half-order singularities (or zeros) at the boundaries of integration.

ON RESTRICTED INFRAPOLYNOMIAL. I---EXISTENCE AND PROPERTIES OF K-FOLD RESTRICTED INFRAPOLYNOMIALS OF ARBITRARY DEGREE n ($\geq k + 1$), AND THEIR STRUCTURE FOR $n = k + 1$. II---INFRAPOLYNOMIALS WITH PRESCRIBED CENTER OF GRAVITY OF THE ZEROS. M. Fekete and J. L. Walsh. Harvard U. Rep. (OSR TN 56-263), June, 1956. 26 pp. Development of some properties of a special class of infrapolynomials, called k-fold restricted infrapolynomials, which are subject to the condition of the sameness of their leading term, are considered in general sets subject to the side condition that $k + 1$ consecutive first terms (of highest degree in z) should possess preassigned coefficients.

OSCILLATION CRITERIA FOR SECOND-ORDER LINEAR DIFFERENTIAL EQUATIONS. Z. Nehari. Carnegie Inst. Tech., Dept. Math., TR 12 (AFOSR TN 56-262), July, 1956. 26 pp. 12 refs. Development of a more general oscillation criteria which contains Hille's criteria as special cases. Proof is based on the minimum property of the lowest eigenvalue of a differential equation system. In order to obtain sufficient conditions a comparison procedure is used with a given equation whose oscillatory character is known. Formulas are also derived for the asymptotic estimation of the number of zeros in the solutions of certain classes of oscillatory equations.

## MISSILES

AN INTERFERENCE FACTOR FOR MULTIFINNED TAIL ASSEMBLIES IN SUPERSONIC FLOW. J. L. Potter, N. M. Shapiro, and W. D. Murphree. USRA OML Rep. 2R12F, May 18, 1956. 49 pp. Experimental and theoretical investigation to determine methods of calculating normal forces and center of pressure of multifinned tail assemblies in supersonic flow. Data for four-, six-, and eight-finned tails of typical design are presented in a range of Mach Numbers from 1.73 to 4.24. The solution is based on a multifin interference parameter. One procedure is to calculate the normal coefficient for twin-fin tails by a method such as Morikawa's. When the resulting curve is plotted against the multifin interference parameter, the curve is also applicable to multifin tails. Another procedure to follow if experimental data are available is to plot the normal coefficient for twin-finned tails against the multifin interference parameter, and to use the resulting curve for interpolation purposes. The data also indicate that the number of fins does not significantly influence the center of pressure.

FLIGHT INVESTIGATION OF THE PERFORMANCE OF A TWO-STAGE SOLID-PROPELLANT NIKE-DEACON (DAN) METEOROLOGICAL SOUNDING ROCKET. R. H. Heitkotter. US, NACA TN 3739, July, 1956. 21 pp. Evaluation of a rocket vehicle for upper atmosphere meteorological research, presenting a description of the rocket configuration, the zero-length launching method used, and the flight test results. The vehicle consists of a Deacon rocket containing research apparatus which is ejected in flight, and of a Nike booster. Radar beacon instrumentation is used to record a peak altitude of 356,000 ft. for the first flight test, and 350,000 ft. for the second test run. Flight-test results are presented in the form of data for trajectories, velocities, accelaration, and drag. Performance calculations show that altitudes between 358,000 ft. and 487,000 ft. may be attained with payloads varying between 60 lbs. and 10 lbs.

## NUCLEAR ENERGY

THERMONUCLEAR POWER PLANTS. Hsue-Shen Tsien. Jet Propulsion, July, 1956, pp. 559-

564. Analysis of certain problems in the technical design of a thermonuclear power plant. The thermonuclear reaction rate for the fusion of deuterium is calculated on the basis of a similar Gamow and Teller analysis. Pressure, temperature, and minimum dimensions of the necessary reaction chamber are determined largely by consideration of reaction quenching and energy loss near the walls. Results are presented for the output and the efficiency of a power station utilizing the deuterium fusion reaction. Additional comment is offered by Greenstein on the problem of calculating the reaction quenching and energy loss rates near the walls.

## POWER PLANTS

A THEORETICAL ANALYSIS OF REACTION RATE CONTROLLED SYSTEMS. M. V. Herbert. Gt. Brit., NGTE Rep. R.196, June, 1956. 73 pp. 21 refs. Determination of the absolute limits of air loading for an adiabatic and homogeneous reaction zone taking into account the effects of inlet temperature and vitiation. The performance of a system governed by reaction rate is characterized by three parameters. The first is the efficiency based on temperature rise; the second, an equivalence ratio based on fuel-oxygen ratio; and the third, the combined air loading factor. Application of these terms is made to the stability of baffles and combustion cans. The effects of pressure drop on the reaction rate are also discussed.

### Jet & Turbine

INVESTIGATION OF THE EFFECT OF IMPACT DAMAGE ON FATIGUE STRENGTH OF JET-ENGINE COMPRESSOR ROTOR BLADES. Albert Kaufman and A. J. Meyer, Jr. US, NACA TN 3275, June, 1956. 25 pp. Determination of the effect of type and location of damage on the fatigue strength of compressor blades. Results indicate that the most serious damage is caused by nicks or breaks and tears in the surface of the leading or trailing edges in the vicinity of the maximum-vibratory-stress section of the airfoil. Dents and nicks away from the leading or trailing edges do not reduce the strength. Dents are less serious than nicks, and could be restored by reworking. The strength of seriously nicked blades could not, however, be reliably restored by reworking.

## PROPELLERS

STATIC-THRUST CHARACTERISTICS OF THE NACA 8.75-(5) (05)-037 DUAL-ROTATION PROPELLER. H. T. Norton, Jr. US, NACA RM L56C27, July 10, 1956. 16 pp. Experimental investigation of dual-rotation propellers having six and eight blades at the Langley test stand, to determine the vibratory stress due to blade passage, with wake-velocity surveys and measurements of thrust and torque. Force data is obtained for a blade-angle range of $4^{\circ}$ to $20^{\circ}$, measured at the 0.75 radial station of the front propeller, and the blade angle of the rear propeller, measured at the 0.75 radial station, set $1^{\circ}$ less than the front propeller for most of the tests. The maximum propeller tip Mach Number for the tests is 0.89. Results indicate that: in general, the eight-blade propeller has a higher value of static-thrust figure of merit (because of its better power-absorption qualities) than the six-blade propeller, for all except the lowest values of power coefficient; for a given power coefficient the effect of increasing the tip Mach Number from 0.4 to 0.6 for either the six- or the eight-blade propeller is to increase the value of the static-thrust figure of merit; the effect of the rear propeller on the static-thrust figure of merit of the front propeller is negligible compared with the effect of the front propeller on the rear propeller; the computed total thrust by the empirical method at the lower blade angles is within 5% of the measured thrust; and a difference of $-1^{\circ}$ in blade angles of the front propellers should give equal power at static conditions.

FLUTTER OF THIN PROPELLER BLADES, INCLUDING EFFECTS OF MACH NUMBER, STRUCTURAL DAMPING, AND VIBRATORY-STRESS MEASUREMENTS NEAR THE FLUTTER BOUNDARIES. H. H. Hubbard, M. F. Burgess, and M. A. Sylvester. US, NACA TN 3707, June, 1956. 25 pp. Investigation of flutter of propeller blades with three different plan forms. Results indicate that a highly twisted 2% thick blade has rather complex flutter boundaries and that several modes of flutter are involved. Both the upper and lower flutter boundaries are defined for a 6% thick blade for which the Mach Number effects appear to limit the extent of the flutter region. Increases in the minimum flutter-speed coefficients are noted for increasing structural and hub damping. Internal blade damping is shown to be beneficial in reducing the magnitude of the vibratory stresses of a 3% thick blade during flutter. At some resonance conditions stresses of the same order of magnitude as the flutter stresses are encountered. These stresses are also lower for increased internal blade damping.

## ROCKET SLEDS

SEMINAR REPORTS AND ABSTRACTS OF PAPERS - SECOND EXPERIMENTAL TRACK SYMPOSIUM; Held at Hollywood, Calif., and the Air Force Flight Test Center, Edwards AFB, Sept. 26-28, 1955. Edwards AFB, Calif., USAF FTC, ARDC, 1955. 55 pp. Contents: - Seminars - THE ROLE OF LIQUID PROPELLANTS IN HIGH SPEED TRACK TESTING. INSTRUMENTATION FOR EXPERIMENTAL TRACKS. PARACHUTE DEVELOPMENT TESTING. ESCAPE SYSTEMS TESTING. TRACK TESTING DEVELOPMENT PROBLEMS. FUTURE REQUIREMENTS FOR TRACK TESTING SUPPORT. Abstracts of papers: STATUS REPORT ON SNORT, W. D. Drinkwater. USE OF ROCKET SLEDS IN EXPERIMENTAL WIND BLAST TESTS, J. P. Stapp. THE USE OF SHOCK ISOLATION SYSTEMS, Ernest Coleal. ACTIVITY REPORT ON AFFTC TRACKS, R. L. King. INTRODUCTION TO PROJECT SMART, C. A. Brosterhous. DEVELOPMENT OF A WATER BRAKE RECOVERY SYSTEM, C. T. Hurd. THE

SNORT SYSTEM FOR MEASURING SLED POSITION AND TIME, B. W. Pike. ABERDEEN PROVING GROUND BALLISTIC TRACK, M. E. Bonnett. THE DYNAMICS OF CRASH RESTRAINT HARNESSES, Y. Hiroshige. PARACHUTE TESTING ON THE HIGH SPEED TRACK, R. Berndt. ARMAMENT TESTING ON HIGH SPEED TRACKS, B. R. Egbert. THE FLOW CHARACTERISTICS OF A RAM INLET AND WIND TUNNEL COMBINATION, G. Eber.

## ROTATING WING AIRCRAFT

MINISTRY OF SUPPLY - RD.HELICOPTERS; NOTATION FOR ROTORCRAFT WORK. A. Armitage. Gt. Brit., MOS RDH TN 1/56, Apr., 1956. 30 pp. A suggested standard notation for rotating wing aircraft work, resulting from a study of numerous papers of many sources of origin. Contents: general symbols and physical quantities, parameters at the rotor disc, airflow parameters at a blade element, rotor blade motion, and stability and control. An omnibus list of symbols is included.

HELICOPTER BLADE VIBRATION AND FLUTTER. R. H. Miller and C. W. Ellis. AHS J., July, 1956, pp. 19-38. Discussion and analysis of a method to reduce helicopter vibration arising from vertical forces acting at the rotor hub by placing the blade in torsional resonance with the dominant harmonic and by adjusting the chordwise c.g. in such a way as to cancel the aerodynamic exciting force, regardless of its origin. Includes analysis of the blade stability boundaries, taking into account the effects of elastic deflections in bending, and a lag hinge. Results indicate that a very close relation exists between the degree of blade stability and the response of the rotor to vibratory airloads, and that a substantial reduction in vibratory shear forces produced by the rotor in a given flight condition can be made by the proper choice of rotor blade c.g. position and torsional restraint: reduction to less than 1/3 the value of shear produced by a torsionally rigid blade is practical even in the absence of resonant elastic flapping.

SOME NEW CONCLUSIONS ABOUT HELICOPTER MECHANICAL INSTABILITY. Troels Warming. AHS J., July, 1956, pp. 1-9. Theoretical investigation taking into account all acting forces and moments in order to derive the necessary equations from the condition of their equilibrium. The analysis is limited to rotors with three or more blades, and the pylon considered is a concentrated mass at the center of the hub, which can move in the plane of rotation. The spring and damping forces acting on the pylon are the same in all directions (isotropic mounting). Results indicate that the effect of the rotor on the pylon is that of added inertia and damping, both of which may be negative. The added inertia changes the pylon natural frequency so that instability may occur outside the generally accepted range. The two conditions for stability are that the product of pylon and blade damping, as well as the blade damping itself, exceed certain values. It is further shown that a helicopter may be stable at its center of instability, but unstable at higher speeds.

## SPACE TRAVEL

FACTORS AFFECTING THE LIFETIME OF EARTH SATELLITES. N. V. Petersen. Aero Dig., July, 1956, pp. 74-82. Discussion of perturbing forces on satellite stability. Such forces include nonsphericity of the earth, anomalies in the earth's crust, and drag due to immersion of the satellite in earth's atmospheric envelope.

THERMAL CONTROL IN A SPACE VEHICLE. P. E. Sandorff and J.S. Prigge, Jr. J. Astronautics, Spring, 1956, pp.4-8, 26. Analysis, based on estimated performance for actual conditions and materials, to calculate the temperature distribution on the hull of a space vehicle subject to solar radiation but not to earth shine, with the hull assumed to be of high-strength aluminum alloy and spherical in shape. The problem of establishing and maintaining control of the temperature inside of the vehicle is treated as an engineering design problem. Use of the "thermos bottle principle" in connection with a Whipple meteor shield is seen as a practical answer to isolation of the vehicle proper from the heating and cooling effects of radiation. Other possible solutions to thermal problems encountered by specific vehicles include the utilization of heat storage capacity, shadow transit times, and reflectance points for short periods.

## STRUCTURES

A CREEP BUCKLING HYPOTHESIS. George Gerard. J. Aero. Sci., Sept., 1956, pp. 879-882, 887. 10 refs. Formulation of the creep-buckling phenomenon in terms of classical stability theory which permits the extension of known solutions for plastic buckling of certain thin plates and shells to creep-buckling problems and eliminates the need for complex initial-imperfection analyses. Available test data on creep buckling of columns, for which the compressive creep properties are known, are used to check the theory.

NON-LINEARITY OF CORRUGATED DIAPHRAGMS. J. A. Haringx. Appl. Sci. Res., Sect. A, No. 1, 1956, pp. 45-52. Calculation, using an analytic method developed for determining the rigidity of corrugated diaphragms, of the degree of nonlinearity of the relations between load and deflection to be expected for large deformations. The diaphragm is assumed to be thick, and the total amount of energy accumulated in the deflected diaphragm is determined from the line of deflection derived by Haringx, and by taking into account the deformation in the plane of the diaphragm. The corresponding load is determined by identification of the external work done during a virtual increase in the deflection with the related increase in the internal energy of deformation. By means of an example it is shown that the introduction of corrugations into the flat plate, though unavoidably increasing the initial rigidity, involves an important gain in maximum deflection for the same degree of nonlinearity.

BESTIMMUNG DER RANDVERSCHIEBUNGEN BEI EBENEN SPANNUNGSPROBLEMEN. Udo

Wegner. ZAMM, May-June, 1956, pp. 192-198. In German. Derivation of a simple principle of variation for the approximate computation of the necessary potential function required in the calculation of edge-displacement in stress problems. Results of the analysis indicate that the solution of such calculations for disc-shaped bodies depends on the determination of a potential, rather than a bipotential function.

O PREDSTAVLENII OSNOVNIKH SOOTNOSHENII NELINEINOI TEORII OBOLOCHEK. N. A. Alumiae. Prikl. Mat. i Mekh., 1956, pp. 136-139. In Russian. Discussion of the basic relationships in the nonlinear theory of shells, analogous to Novozhilov's presentation in the linear theory. Formal symmetrical tensors of tangent stresses and momenta are introduced, as well as the symmetrical tensors of deformation. This results in a relatively simple analogy between static and geometrical expressions. Main relationships are derived for the determination of the critical value of the momentless initial stressed state.

## Bars & Rods

FATIGUE CRACK PROPAGATION IN SEVERELY NOTCHED BARS. W.S. Hyler, E.D. Abraham, and H.J. Grover. US, NACA TN 3685, June, 1956. 31 pp. 10 refs. Fatigue tests in rotating bending on severely notched bars machined from 2024-T4 aluminum-alloy extruded round rods. Two sizes are studied, 1/4-inch-diameter and 2-inch-diameter specimens. Cracks in large-diameter specimens have a period of rapid crack growth followed by a marked tapering off in rate of crack propagation. Includes a qualitative demonstration of the presence of compressive residual stresses, supposedly associated with the crack behavior.

## Beams & Columns

FORCED RESPONSES OF TWO ELASTIC BEAMS INTERCONNECTED BY SPRING-DAMPER SYSTEMS. Michael Dublin and H. R. Friedrich. J. Aero. Sci., Sept., 1956, pp. 824-829, 887. Description of a theoretical method to determine the forced responses, with numerical results for a simplified configuration. The theory, which assumes elastic beams having variable mass, stiffness, and structural damping distributions, is practically applicable in the investigation of forced responses during rough water taxiing of a seaplane equipped with hydroskis, and in other forced vibration problems where the elasticity of beams is important. Includes remarks on how to use the results for obtaining the responses due to an arbitrary force input.

ON THE ELASTIC FAILURE AND THE BUCKLING OF A COLUMN UNDER ECCENTRIC LOADS. Shosaburo Negoro. Kyushu U., Rep. Res. Inst. Appl. Mech., Oct., 1955, pp. 41-56. Analysis using Sunatani's buckling theory and assuming the columns to be prismatic bars of uniform cross section hinged at both ends, to determine whether elastic failure occurs when the greatest skin stress in the column reaches the stress at the yield point of the material. Results of investigation using previously derived formulas for the bending of a strut under axial loads indicate that the greatest bending moments occur in columns with arbitrarily formed cross sections which are loaded in such a way that one of the principal axes of the cross section is in the bending plane caused by eccentric loads, and in columns with circular cross sections which are so loaded that, in general, the principal axes of the cross section are outside of the aforementioned bending plane. Formulas for the buckling of such columns are derived from the moment and bending formulas.

## Cylinders & Shells

BENDING TESTS OF RING-STIFFENED CIRCULAR CYLINDERS. J. P. Peterson. US, NACA TN 3735, July, 1956. 14 pp. Experimental investigation of 25 ring-stiffened cylinders loaded to failure in bending. The main structural parameters varied in the tests were the ratio of ring spacing to radius, and the radius-thickness ratio; also the geometric size of the cylinders was varied. The rings used were heavy in order to eliminate general instability type failures which involve simultaneous failure of the cylinder wall and of the rings. Test results are presented as design curves for cylinders subjected to local buckling. The curves predict higher failing stresses than previous curves now in use which are based on tests of one-bay compression cylinders.

DYNAMIC BUCKLING TESTS OF ALUMINUM SHELLS. A. F. Schmitt. Aero Eng. Rev., Sept., 1956, pp. 54-58. Investigation of thin-walled, unstiffened shells buckled by the axial impact of high-velocity masses, in order to determine the magnitudes of peak loads developed, the character of the load-deformation relationship, and the energy absorbed by the member during deformation. Results indicate that the energy absorbed in the dynamic buckling of a pure shell is greater than that absorbed in slow, static collapse, the ratio of these energies increasing with the increasing impact velocity over the range of velocities tested (up to 500 in. per sec.) and probably beyond that, through any range of velocities normally anticipated in vehicle crashes. An initial instability pattern, whose failure mode is of the same diamond pattern as experienced in static tests but develops uniformaly over the entire shell evolves rapidly following the impact, and the wave lengths of these patterns decrease with tests of increasing impact velocity. As the failure progresses during a dynamic test, an intense local crippling action develops adjacent to the moving bulkhead with the bulkhead appearing to chew its way along the specimen. The assumption that the finer, more general instability pattern developed under impact results in the bending and twisting of more material during subsequent collapse, accounts for the increase of energy absorption. Parameters are given for the successful reduction of energy-absorbed data from various dynamic tests.

**BEITRAG ZUR FRAGE DER BEULUNG DÜNNWANDIGER AXIAL GEDRÜCKTER KREISZYLINDER.** W. Thielemann and H. J. Dreyer. DVL Bericht No. 17, June, 1956. 29 pp. 11 refs. Westdeutscher Verlag, Köln & Opladen. In German. Results of experiments for the determination of buckling stresses in thin-walled circular cylinders subjected to axial pressure, indicating considerable variation between the calculated data and the classical theory of stability. The calculation is based on an extension of von Karman-Tsien and Donnell theory for large deformations in cylindrical shells.

## Elasticity & Plasticity

**INELASTIC COLUMN BUCKLING.** L. H. Larsson. J. Aero. Sci., Sept., 1956, pp. 867-873. Theoretical investigation of the inelastic buckling process in order to compare the maximum load with the tangent modulus and reduced modulus loads and to derive an exact theory of the centrally compressed, initially slightly curved column. An approximate solution is described which is based on the assumption that the deflection curve is a half sine wave, and it is numerically illustrated for a straight column. Results show that the tangent modulus theory in most cases yields a better approximation for the maximum load supported by a centrally loaded, initially straight column than does the reduced modulus theory.

**ESHCHE RAZ K VOPROSU O TSILINDRICHESKOI FORME POTERI USTOICHIVOSTI UPRUGO-PLASTICHESKIKH PLASTINOK.** Iu. R. Lepik. Prikl. Mat. i Mekh., 1956, pp. 140-143. In Russian. Study of the cylindrical form of the loss of stability of a rectangular plate under the assumption that the deflection of the plate is relatively small, and that, in the case of greater deflection, areas of secondary plastic stresses occur in the plate, reducing its resistance to any further bending. The plate is considered as rather long in one direction, uniformly compressed in the perpendicular direction, and having freely supported edges. The material of the plate is assumed incompressible, and plastic deformations prior to the loss of stability small when compared with elastic stress.

## Plates

**CREEP DEFLECTION OF VISCOELASTIC PLATE UNDER UNIFORM EDGE COMPRESSION.** T. H. Lin. J. Aero. Sci., Sept., 1956, pp. 883-887. 18 refs. Derivation of the stress-strain-time relationship (expressed as a Laplace transform) of a viscoelastic body under plane stress, and description of a method for determining the deflection-time curve of a viscoelastic plate under edge thrust by obtaining the sum of the magnified terms at different instants of the double sine series by which the initial deflection is expressed. The equilibrium condition for the plate is shown in terms of lateral deflections. Results of analysis indicate that the shape of the deformed surface generally changes with time.

**BENDING OF A CIRCULAR PLATE WITH AN ECCENTRIC CIRCULAR PATCH SYMMETRICALLY LOADED WITH RESPECT TO ITS CENTRE.** W. A. Bassali and R. H. Dawoud. Proc. Cambridge Philos. Soc., July, 1956, pp. 584-598. Derivation of expressions for the slope and cross-couples over the boundary and for the deflections at the centers of the plate and the loaded patch from solutions, obtained through the use of the complex variable method, for the deflection of the described circular plate under the general boundary condition including four special cases. These solutions are used to predict the deflection at any point on such a plate.

**ÜBER DIE BEULUNG ANISOTROPER PLATTENSTREIFEN.** W. Thielemann. DVL Bericht No. 16, June, 1956. 70 pp. 18 refs. Westdeutscher Verlag, Köln & Opladen. In German. Determination of buckling loads (using the exact method) of anisotropic flat strips whose moment-free mounted or fixed edges are subjected to uniformly distributed pressure. For the case of sheer pressure loading a diagram is presented in general form for the buckling loads of arbitrarily anisotropic flat strips depending only on two stiffness coefficients for isotropic plates. Application of results of the buckling theory to anisotropic cases.

**STUDY OF SIZE EFFECT IN SHEET-STRINGER PANELS.** J. P. Doman and E. B. Schwartz. US, NACA TN 3756, July, 1956. 25 pp. Investigation to determine whether there are significant size effects in compressive strength of large Z-stiffened sheet stringer panels as compared with geometrically similar smaller models, and to determine whether the prediction of the strength of large panels by model tests is reliable. Four representative types of panels are studied with full-scale and one-quarter-scale panels of each type. Results indicate that size effects are neglible in the compressive strength of large-scale stiffened panels tested as compared with geometrically similar small-scale panels.

## Testing

**HIGH TEMPERATURE STRAIN GAGE RESEARCH.** Ed. by F. G. Tatnall. **I---ADVANCES IN THE ART OF HIGH TEMPERATURE STRAIN GAGES.** F. N. Singdale. **II---HIGH TEMPERATURES STRAIN SENSITIVE ALLOYS.** Eugene Cohn, A. L. Abrams, Frank Gagliano, and Otto Schmitt. **III---PRINTED CIRCUIT AND WIRE MESH HIGH TEMPERATURE STRAIN GAGES.** Hyman Leggett. **IV---PRELIMINARY REPORT ON HIGH TEMPERATURE SYNTHETIC MICA STRAIN GAGES.** G. A. Brewer. **V---EXPERIMENTAL PRODUCTION OF ADHERENT OXIDE FILMS SHOWING PROMISE AS HIGH TEMPERATURE STRAIN GAGE SUPPORTS.** R. E. Fearon. **VI---THE EXTENSOMETER MICROMETER.** USAF WADC TR 55-209, May, 1955. 48 pp.

## Thermal Stress

THERMAL STRESSES IN VISCOELASTIC STRUCTURES. William Prager. ZAMP, May 25, 1956, pp. 230-238. Analysis of the thermo-mechanical behavior of a statically indeterminate truss which consists of Maxwell bars, taking into account the effects of typical variations of loads and temperatures on truss stresses. The principle of virtual displacements is used throughout the analysis. Solutions are obtained for homogeneous trusses where relaxation time is the same for each bar, and for nonhomogeneous trusses where the dependence of the relaxation time on the average temperature must be taken into account, owing to different materials or to the difference of their average temperatures.

SOME EFFECTS OF JOINT CONDUCTIVITY ON THE TEMPERATURES AND THERMAL STRESSES IN AERODYNAMICALLY HEATED SKIN-STIFFENER COMBINATIONS. Appendix A - SPECIAL CASE OF ZERO JOINT CONDUCTIVITY. Appendix B - DIFFERENTIAL EQUATIONS FOR CALCULATING TEMPERATURES. Appendix C - THERMAL-STRESS EQUATIONS. Appendix D - NONDIMENSIONAL RATIOS. G. E. Griffith and G. H. Miltonberger. US, NACA TN 3699, June, 1956. 62 pp. Investigation of aerothermo-effects in skin-stiffener combinations for different aerodynamic conditions, carried out in nondimensional form with an electronic differential analyzer. Variations are made in the aerodynamic heat transfer parameter, in the joint conductivity parameter, and in the ratio of skin width to skin thickness. Results indicate that: a decrease in the joint conductivity parameter lowers both the interior and the average temperature ratios, increases the peak thermal stress ratios in the skin, and may considerably increase the peak stiffener stress ratios; an increase of the aerodynamic heat-transfer parameter decreases the interior and average temperature ratios, increases the peak skin stress ratios somewhat, but greatly increases the peak stiffener stress ratios; and an increase in the ratio of skin width to skin thickness produces only a moderate decrease in the peak skin stress ratios while moderately increasing the peak stiffener stress ratios.
atures. An example of combined loads and temperature effects is obtained by assuming a certain variation resulting in a maximum loading intensity when the temperature differences vanish, and vice versa.

## THERMODYNAMICS

INTRODUCTION TO IRREVERSIBLE PROCESSES. J. de Boer. U. Wis. NRL Dept. Chem. Rep. WIS-AF 2, July 26, 1956. 27 pp. Explanation of the theory with illustrative examples. Covers: thermodynamics of irreversible processes, evaluation of irreversible entropy production in simple systems, cross-effects in thermodynamics of irreversible processes, the principle of minimum entropy production and Thomson's method, irreversible processes and Brownian motion, and proof of the Onsager relations.

## Combustion

STABILITY OF SYSTEMS CONTAINING A HEAT SOURCE - THE RAYLEIGH CRITERION. Boa-Teh Chu. US, NACA RM 56D27, June 26, 1956. 25 pp. 10 refs. Analysis of oscillatory phenomena is systems containing an energy source to establish the condition under which a small disturbance is amplified in the course of time by its interaction with a heat source. Application is made to two special cases, first, when the heat source is a plane heater and there is a current of air through a tube with Mack Numbers of the order of magnitude of 0.01 or less, and the second, when the heat source is a flame front. In the case of a flame, it is found that the Rayleigh criterion must be modified slightly if the specific-heat ratios of the burned and unburned gases are different.

SPECTROGRAPHIC EXAMINATION OF GASEOUS FLAMES AT HIGH PRESSURE. J. Diederichsen and H. G. Wolfhard. Proc. Royal Soc. (London), Ser. A, July 10, 1956, pp. 89-103. 12 refs. Investigation into the light emission of both premixed and diffusion flames burning at pressures up to 40 atmospheres. Results indicate that the equipartitioning of energy released by chemical reaction is faster at high pressures. This leads to the suppression of unstable radicals which are observed in low pressure flames. The radiation of oxygen flames is mainly determined by the increase in temperature of flames burning at high pressure, and leads to a strong increase in the emission from the products which are present in equilibrium such as OH and $O_2$. Continuous gas radiation increases very strongly with pressure and two types of continua can be distinguished, the carbon monoxide flame continuum, and the hydrogen flame continuum. This continuous radiation is responsible for most of the light emitted from high pressure flames.

SPACE HEATING RATES FOR SOME PREMIXED TURBULENT PROPANE-AIR FLAMES. B. D. Fine and P. Wagner. US, NACA TN 3277, June, 1956. 26 pp. 10 refs. Experimental investigation extending Simon-Wagner results to measurements over a larger range of flow conditions in order to evaluate critically the concept and its utility, and to investigate directly the generality of the equation $Z = 6.1\ U_L/d$. Procedures used are the stabilization of piloted turbulent propane-air flames above burners in fields of pipe-induced turbulence, and visual measurement of flame volumes from negatives of time-exposure photographs. Space conversion and space heating rates are calculated and their behavior examined with respect to changes in stream velocity, burner diameter, laminar burning velocity, and pilot conditions. In addition, turbulent burning velocities are calculated, and the relation between turbulent burning velocity and space conversion rate is examined.

## Heat Transfer

EFFECT OF PHOSPHATE COATINGS ON TEMPERATURE OF METAL PARTS EXPOSED TO FLAME ENVIRONMENTS. G.C. Fryburg, N. H.

Katz, and S. L. Simon. US, NACA TN 3279, July, 1956. 20 pp. 11 refs. Investigation of the effect of phosphate coatings on the temperature of a metal surface. Cylindrical specimens of mild steel and S-816 alloy are heated in a natural gas flame. For both types of metals, coated specimens maintain a lower temperature even after being subjected to the flame for 300 hours. Results also indicate that the temperature lowerings arise primarily from the high emittance of the phosphate coating rather than from a poisoning action.

## WATER-BORNE AIRCRAFT

PRELIMINARY INVESTIGATION OF SELF-EXCITED VIBRATIONS OF SINGLE PLANING SURFACES. E. J. Mottard. US, NACA TN 3698, June, 1956. 19 pp. Tests on a practical hydro-ski configuration to determine the effects of varying some of the structural and geometric properties and to determine the degrees of freedom required for the vibrations to occur. Results indicate that self-excited vibrations occur with a high aspect ratio of the wetted portion may occur without a change in trim angle, and can be decreased in severity or eliminated by the use of planing surfaces which limit the aspect ratio. A 60% increase in the thickness of the hydro-ski causes a definite increase in the speed at which the vibration first occurs, and a 70% decrease in the overhang eliminates the vibration for the ranges of speed and load investigated.

## WIND TUNNELS & RESEARCH FACILITIES

TRANSONIC WIND TUNNEL TEST SECTIONS. P. F. Maeder and A. D. Wood. ZAMP, May 5, 1956, pp. 177-212. 48 refs. OSR-sponsored review of the flow phenomena in transonic wind tunnels taking into account blockage, angle of incidence, buoyancy, and streamline curvature interferences. It is determined that the optimum properties of a transonic tunnel result from the use of a combination of solid wall and open jet boundaries, and various combinations of these are examined. For subsonic flow the blockage interference on the model and the buoyancy interferency on the wake can be eliminated by proper choice of a longitudinal slot configuration. The angle of incidence correction and the streamline curvature interference are evaluated for a rectangular test section with top and bottom walls slotted, and for a slotted circular test section. For perforated walls blockage and buoyancy effects can be evaluated, but the angle of incidence correction is known only for a circular tunnel, and streamline curvature interference effects are not known. In supersonic flow the perforated wall seems to perform more satisfactorily for the two dimensional case, with complete wave cancellation possible. In the slotted wall better attenuation is obtained in the three-dimensional case.

A DESIGN OF ELECTRICAL CONTROL HEATERS FOR OPERATION WITH A SUPERSONIC, BLOW-DOWN WIND TUNNEL. R. A. Fetter, Jr. U. Tex. DRL Rep. 382 (AFOSR TN-188), June, 1956. 76 pp. 17 refs. Development of a 420-kw. electrical resistance heater to maintain a constant air stagnation temperature in supersonic wind tunnels. The heating unit consists of a stainless steel Inconel box containing filaments of Nichrome V wire, held in place by ceramic beads. Three such units are arranged end to end in a heavy pipe casing. An oscilloscope equipped with camera is used to record the heater current wave forms. Three self compensating printing recorders are used to register various temperatures in the tunnel circuit. Power input is controlled by potentiometers which determine the point on the cycle at which the ignitions permit the current to pass.

CALIBRATION OF THE FLEXIBLE PLATE NOZZLE IN THE TRANSONIC MODEL TUNNEL OF THE PROPULSION WIND TUNNEL. J. C. Marshall. USAF AEDC TN-56-5, June, 1956. 36 pp. Discussion of the tunnel calibration for measuring the flow quality in the nozzle, with emphasis on the Mach Number distribution along the axial centerline of the nozzle. Pressure measurements are made at 16 points along the centerline, and local Mach Number is computed from local static pressure and the stilling chamber total pressure. Influences of jack deflections on Mach Number are determined, and used in an attempt to improve the flow quality. Only small correction is possible owing to the fact that there are only three jack stations in the supersonic region of the nozzle. Flow angularity measurements with a yaw probe indicate that the asymmetry of the nozzle is small.

THE APPLICATION OF THE SHOCK TUBE TO THE STUDY OF THE PROBLEMS OF HYPERSONIC FLIGHT. A. Hertzberg. Jet Propulsion, July, 1956, pp. 549-554, 568. 18 refs. Description of the shock tube capable of generating the high temperature conditions in air encountered in hypersonic flight, with a presentation of design modifications studied at CAL. Results point out that if the conventional shock tube is terminated by an expansion nozzle, high Mach Number flows can be achieved as well as high stagnation temperatures. Actual flow conditions can therefore be closely simulated for the investigation of heat transfer rates and other aerodynamic problems. The application of the shock tube to other areas of high temperature research is briefly discussed, in particular a technique for the study of high temperature chemical reaction rates.

APPARATUS AND TECHNIQUES FOR THE APPLICATION OF A WATER FLOW SYSTEM TO THE STUDY OF AERODYNAMIC SYSTEMS. E. F. Winter and J. H. Deterding. Brit. J. Appl. Phys., July, 1956, pp. 247-261. Development of an apparatus in which the flow of water may be studied in transparent models of simulated air systems. The flow is rendered visible by plastic tracers of density similar to water, which are illuminated by lamps. Details are given for the apparatus along with examples of some of the types of information obtainable, and the requirements for similarity with aerodynamic systems are stated.

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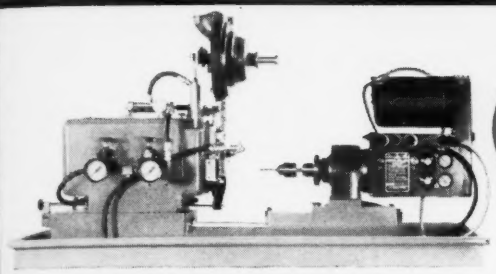
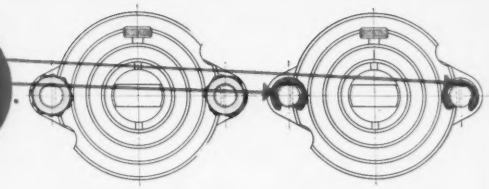
# Waldes Truarc Retaining Rings Eliminate Machining and Parts—Cut Assembly Time on Drill and Tapper



## Beco Model 410 Drill and Tapper

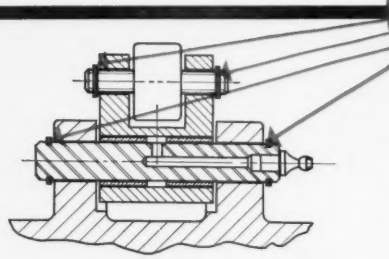
The Batchelder Engineering Co., Inc., Springfield, Vermont uses 4 different sizes of 2 different type Waldes Truarc rings in their new BECO Model 410 Automatic Drill and Tapper. Truarc rings speed assembly, reduce machining, improve design.



ALTERNATE DESIGN TRUARC DESIGN

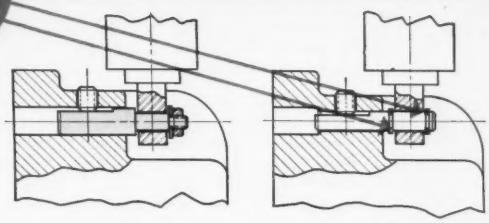
## Clamp Cylinder Rod Stop Assembly

Truarc "E" Rings (Series 5133) replace stop nuts in the Clamp Cylinder assembly. They eliminate need for threading 2 rods ...the danger of cross-threading nuts...and costly rejects. Truarc Rings cut assembly time and cost.



## Bell Crank Pivot Assembly

Truarc Rings (Series 5100) in Bell Crank Pivot assembly permit grease hole not possible with cotter pin fastener. Use of nuts would have increased machining and assembly costs considerably.



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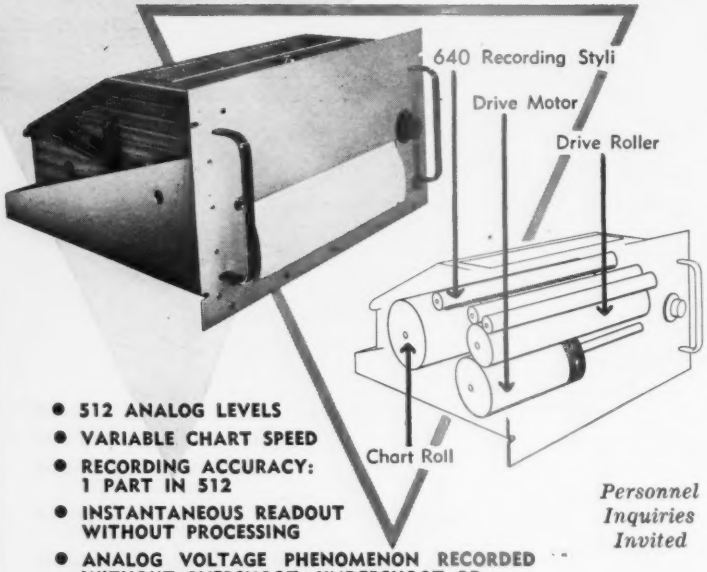


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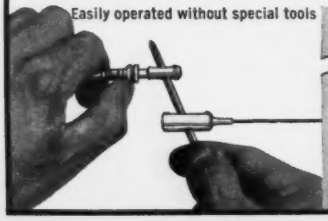


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capacity of a communication system used for aircraft control during airport traffic control, ground-controlled approach, and ground-controlled landing.

**Recent Developments in the Simulation of Terminal Area and En Route Area Air Traffic Control Problems.** T. K. Vickers and R. S. Miller. *IRE Trans., ANE Ser.*, June, 1956, pp. 51–55.

### *Networks*

**The Design of Low Frequency High-Pass RC Filters.** D. D. Crombie. *Electronic Eng.*, June, 1956, pp. 254–256. Discussion of the theory of a high-pass filter which uses a twin-T network, with the twin-T transfer characteristics modified by inclusion in a feedback amplifier having suitable phase shift; and consideration of the choice of compensating circuits for flattening the pass-band in order to arrive at an optimum design procedure.

**On the Synthesis of 3-Terminal RC Networks.** K. M. Adams. *Coll. of Aeronautics, Cranfield, Rep. 96*, Jan., 1956. 43 pp. Derivation of necessary conditions for physical realizability from first principles by an algebraic method.

### *Noise & Interference*

**Designing Low-Noise Equipment. IV.** W. R. Bennett. *Electronics*, June, 1956, pp. 154–157. 25 refs. Discussion of design criteria for reducing the effects of random noise in an amplifier. The objective is to reach a sufficient gain in the first one or two stages to make the noise requirements on the remainder of the equipment relatively lenient. Discussion includes advantages of pentode and cascode amplifiers, special high-frequency considerations, and techniques for handling random noise in transistors, klystrons, and traveling wave tubes.

**Reducing Noise in Communications Systems. V.** W. R. Bennett. *Electronics*, July, 1956, pp. 148–151. Discussion of a method for reducing noise by the use of a pulse-code modulation exchanging bandwidth for an improved signal-to-noise ratio. This also permits the regeneration of pulses which have become distorted, and detects and corrects codes.

**Visual Detectability of Signals in Noise; The Effect of "Contrast."** J. W. R. Griffiths. *Wireless Engr.*, May, 1956, pp. 118–120. Theoretical analysis of the effect of contrast, in the form of a bias, on a particular derived signal-to-noise-ratio criterion ($R_{B2}$).

### *Oscillators & Signal Generators*

**Superregenerative Transistor Oscillator.** R. J. Kircher and I. P. Kaminow. *Electronics*, July, 1956, pp. 166, 167. Description of a simple transistor circuit which produces equal on-off intervals of 500-cps tone at a rate of 7 cps. The circuit requires one junction transistor and provides 23 milliwatts of pulse power to a 600-ohm load.

### *Radar*

**An Improved Simultaneous Phase Comparison Guidance Radar.** Howard H. Sommer. *IRE Trans., ANE Ser.*, June, 1956, pp. 67–70. Description of a radar

unit to provide the control system with the proper signals for guidance in proportional navigation, and to solve some of the practical difficulties involved in existing equipment.

**Three-Dimensional Radar Video Simulator.** Peter Pielich. *Electronics*, July, 1956, pp. 131–133. Development of a three-dimensional oscilloscope display for providing terrain-clearance radar data by the use of a simulated-video generator and a conventional flying-spot scanner.

**Optical Simulation of Radar.** W. Blitzstein and T. Levine. *Tele-Tech*, June, 1956, pp. 110, 111, 190–192. Development of a device to simulate targets by spots of light moving across a screen which trace aircraft-type trajectories.

**The Reduced Range in a Radar Subjected to an External Noise Generator. Appendix I—Derivation of Reduced Range Formulas in the Case of Low Height on Plane Sea Surface, $\lambda/h$ Being Small. Appendix II—Derivation of Reduced Range Formulas in the Case of Low Height on Curved Sea Surface, $\lambda/h$ Having a Small Value.** Ugo Tiberio. *U. Pisa, Eng. Fac. Rep. 737*, 1954. 8 pp.

**The Effect of AGC on Radar Tracking Noise.** R. H. Delano and Irwin Pfeffer. *Proc. IRE*, June, 1956, pp. 801–810. Investigation by analog simulation of the automatic gain control for an ordinary linear filter in the feedback path and for a nonlinear filter with quick attack and slow release in the loop, and analytic description of the transient rise in average signal strength encountered by a radar when closing rapidly on a target.

*Resistors*

**Characteristics of Fixed Resistors; Sources of Noise, Resistance at High Frequency and Some Measurements on Carbon Composition Resistors.** G. W. A. Dummer. *Wireless World*, June, 1956, pp. 263–265.

**Frequency Conversion with Positive Nonlinear Resistors.** Chester H. Page. *U.S., NBS J. Res.*, Apr., 1956, pp. 179–182. Method of determining the modulation of nonlinear resistors by representing the power as a uniformly convergent trigonometric series.

*Semiconductors*

**Formation of *p-n* Junctions in Semiconductors by the Variation of Crystal Growth Parameters.** Henry E. Bridgers. *J. Appl. Phys.*, July, 1956, pp. 746–751. Application of the theory of Burton et al. for the variation of the effective distribution coefficient with growth rate and stirring, to the formation of *p-n* junctions by "rate growing" and "stirring modulation." Includes derivation of the general principles and discussion of other applications.

**The Forward Characteristic of the PIN Diode.** D. A. Kleinman. *Bell System Tech. J.*, May, 1956, pp. 685–706. Development of a theory for the forward current-voltage characteristic of the diffused junction diode, with results indicating that the presence of the middle region causes no significant deviation in the voltage characteristic from that of a simple PN diode until very high current densities are reached, of the order of 200 amp./cm.$^2$ in silicon.


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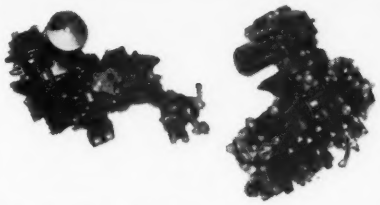

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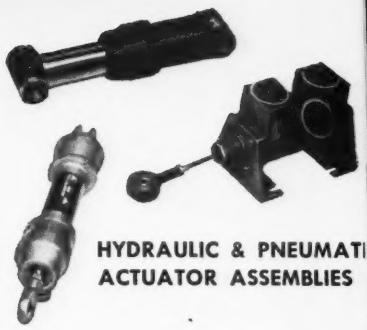

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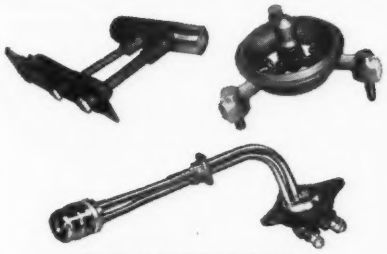

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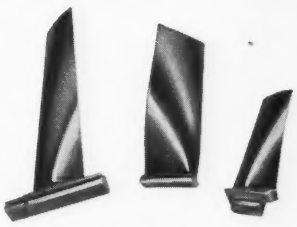

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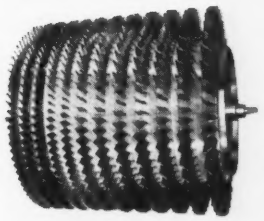

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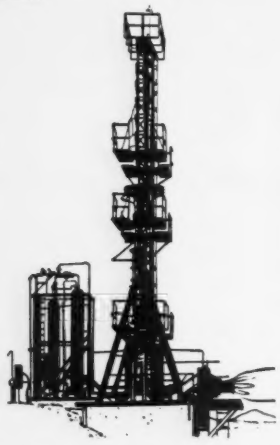

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**Reverse Current and Carrier Lifetime as a Function of Temperature in Silicon Junction Diodes.** E. M. Pell and G. M. Roe. *J. Appl. Phys.*, July, 1956, pp. 768–772. 11 refs.

**Diffusion Effects in Drift Mobility Measurements in Semiconductors.** J. P. McKelvey. *J. Appl. Phys.*, Apr., 1956, pp. 341–343.

*Telemetry*

**Telemetering Demodulator for Wide-Band F-M Data.** T. D. Warzecha. *Electronics*, July, 1956, pp. 157–159. Design of a demodulator which converts FM to pulse frequency modulation where a narrow pulse is generated for every cycle of the translated subcarrier wave.

**Shipboard Telemetering for Terrier Missiles.** William S. Bell and Clarence W. Schultz. *Electronics*, June, 1956, pp. 134–137. Description of telemetering equipment installation for the evaluation of missile performance and for the simultaneous accommodation of six missiles.

*Transmission Lines*

**An Investigation into Some Fundamental Properties of Strip Transmission Lines with the Aid of an Electrolytic Tank.** J. M. C. Dukes. (*IEE Paper 1991 R.*) *Proc. IEE, Part B*, May, 1956, pp. 319–333. 28 refs. Description of a method which provides an exact analog of the electric field in any cross section of the line and may be used to evaluate numerical results whose accuracy depends only on the degree of precision employed. Also development of a new technique which avoids the use of movable probes and permits very rapid evaluation of quantities such as attenuation.

**On the Theory of a Coaxial Transmission Line Consisting of Elliptic Conductors.** J. Y. Wong. *Can. J. Phys.*, Apr., 1956, pp. 354–361.

**Non-Uniform Transmission Lines as Impedance Transformers.** J. Willis and N. K. Sinha. (*IEE Paper 1961 R.*) *Proc. IEE, Part B*, Mar., 1956, pp. 166–172. 18 refs. Consideration of the equation for the reflection coefficient at one end of a line matched at the other end to derive an approximate form of solution in order to permit the design of lines as matching sections for optimum performance.

**Waveguide Filters; Narrow Band with Quarter-Wave Transformers.** M. H. N. Potok. *Wireless Engr.*, Apr., 1956, pp. 79–82. Analysis showing that high-Q, low-frequency transmission filters can be obtained by the comparatively simple method of building up a chain of alternately high and low quarter-wave transformers.

**Variational Principles for Electromagnetic Resonators and Waveguides.** A. D. Berk. *IRE Trans., AP Ser.*, Apr., 1956, pp. 104–111. 10 refs. Presentation of variational expressions for the propagation constants of a wave guide and for the resonant frequencies of a cavity directly in terms of the field vectors.

**A New Treatment of Lossy Periodic Waveguides.** P. N. Butcher. (*IEE Paper 1969 R.*) *Proc. IEE, Part B*, May, 1956, pp. 301–306. Description of a theoretical method which is particularly applicable to the design of electronic devices, such as the $\pi$-mode linear accelerator, which operate near the edge of a pass-band. The method yields information about the effects of the losses on the phase-change coefficient and permits calculation as the frequency approaches the edge of the pass-band from within and inside a stop-band.

*Wave Propagation*

**Design of Microwave Filters with Quarter-Wave Couplings.** G. Craven and L. Lewin. *Proc. IEE, Part B*, Mar., 1956, pp. 173–177. Measurements at 4,000 mc. in 2- by 2/3-in. wave guide to demonstrate that, with suitable modification of the obstacles used, the shorter connecting lengths may be retained without the introduction of noticeable mutual coupling.

**An Experiment to Test the Reciprocal Radio Transmission Conditions Over an Ionospheric Path of 740 km.** R. W. Meadows. (*IEE Paper 1901 R.*) *Proc. IEE, Part B*, Mar., 1956, pp. 224–226; Discussion, pp. 232–235.

**Directional Observations on H.F. Transmissions Over 2100 km.** E. N. Bramley. (*IEE Paper 2011 R.*) *Proc. IEE, Part B*, May, 1956, pp. 295–300. Experimental investigation using a wide-aperture spaced-loop direction finder for determining the inaccuracies in bearings due to ionospheric effects at this distance as compared to those obtained at shorter distances.

**Long Range Meteoric Echoes via F-Layer Reflections.** J. T. deBettencourt and W. A. Whitcraft, Jr. *IRE Trans., AP Ser.*, Jan., 1956, pp. 72–76. USAF-sponsored HF observations of meteoric backscatter echoes at ranges greatly exceeding radio line-of-sight as part of experimental ionosphere propagation research using COZI equipment.

**An Investigation of the Properties of Radial Cylindrical Surface Waves Launched Over Flat Reactive Surfaces.** W. M. G. Fernando and H. E. M. Barlow. (*IEE Paper 2009 R.*) *Proc. IEE, Part B*, May, 1956, pp. 307–318. 10 refs.

**The Fading Periods of the *E*-Region Coupling Echo at 150 kc/s.** R. W. Parkinson. *J. Atmos. & Terrestrial Phys.*, Mar., 1956, pp. 158–162. 11 refs. USAF ARDC-sponsored study.

**The Fading of Radio Waves of Frequencies Between 16 and 2400 kc/s.** S. A. Bowhill. *J. Atmos. & Terrestrial Phys.*, Mar., 1956, pp. 129–145. 13 refs. Experimental investigation by three methods using c.w. transmissions reflected from the ionosphere at nearly vertical incidence during the night time, with results leading to a suggested model with small irregularities slightly above the 70 kc. reflection level.

**Diffraction of Electromagnetic Waves Caused by Apertures in Absorbing Plane Screens.** Hans E. J. Neugebauer. *IRE Trans., AP Ser.*, Apr., 1956, pp. 115–119. 15 refs. Analysis which shows that the perturbation field caused by holes in a plane, infinitely thin screen of arbitrary material on which electromagnetic radiation is incident can be split up in two fields, one of which is symmetrical to the tangential components of the electric, the other to those of the magnetic, vector. Both fields satisfy equations which are generalizations of the Bethe conditions

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**Diffraction of 3.2 Cm. Electromagnetic Waves by Dielectric Rods. I—Lucite and Tenite 1 in. Diameter Cylinders. II—Lucite 1½ in. Diameter Cylinder and Semicylinder.** A. B. McLay and M. K. Subbarao. *Can. J. Phys.*, June, 1956, pp. 546–562. Measurements of diffraction patterns in several planes transverse to the incident beam direction, with results for the cylinders compared to those theoretically obtained and to those obtained in previous experiments for brass and hard-rubber cylinders. Patterns of the semicylinder are determined with the plain face toward and away from the source of radiation.

**Some Relationships Between Total Scattered Power and the Scattered Field in the Shadow Zone.** J. T. Bolljahn and W. S. Lucke. *IRE Trans., AP Ser.*, Jan., 1956, pp. 69–71. USAF-sponsored derivation of equations which relate the far-zone scattered field, as measured in the scattered zone of an electromagnetic scatterer, to the total energy scattered and absorbed by the scatterer. In the case of a perfectly conducting scatterer, the energy stored in the fields about the scatterer is also related to the far-zone scattered field in the zone shadow.

**Scattering of Electromagnetic Waves by Coaxial Cylinders.** Albert W. Adey. *Can. J. Phys.*, May, 1956, pp. 510–520. 13 refs. Theoretical and experimental investigation of a system incorporating coaxial dielectric cylinders, with calculations of the forward and back scattered fields for several combinations of inner and outer radii, and tests at a wave length of 3.275 cm. using a parallel-plate transition line.

**Turbulent Mixing Theory Applied to Radio Scattering.** Appendix I—**Comparison of the Obukhoff and Villars-Weisskopf Models.** Appendix II—**Comparison of the Obukhoff and Booker-Gordon Models.** Richard A. Silverman. *J. Appl. Phys.*, July, 1956, pp. 699–705. 19 refs. USAF-supported research.

**The Technique of Ionospheric Investigation Using Ground Back-Scatter.** E. D. R. Shearman. (*IEE Paper 1915 R.*) *Proc. IEE, Part B*, Mar., 1956, pp. 210–223; Discussion, pp. 232–235. 27 refs. Measurement of the skip distance in short-wave propagation by observing the time delay of echoes scattered from the earth's surface beyond the skip distance. A theoretical study shows that the method should give good accuracy in determining skip distance, but cannot yield unique values of the height and critical frequency of an ionospheric layer at a distant point. The radar equation is used to find the intensity of back-scatter from the ground and the effect of ray focusing by the ionosphere is considered.

**A Study of Ionospheric Propagation by Means of Ground Back-Scatter.** E. D. R. Shearman. (*IEE Paper 1914 R.*) *Proc. IEE, Part B*, Mar., 1956, pp. 203–209; Discussion, pp. 232–235. 12 refs.

## Equipment

**Field Data Analysis.** B. Larmour and J. E. Neelin. (*CAI Annual Gen. Meeting, Montreal, May 4, 1956.*) *Can. Aero. J.*, June, 1956, pp. 187–196. Consideration of the equipment life (EL) curve, the factors in equipment failures, ways of identifying failure factors in EL curves, complex EL curves, marginal failure probability curves, machine processing techniques, and the overall reliability and some applications of the field data.

### *Electric*

**Electrical Equipment in Aircraft.** S. F. Follett. *The Engr.*, May 11, 1956, pp. 476, 477. Abridged. Discussion of future trends in electrical equipment, taking into account temperature and altitude effects, reliability of equipment, form of power supply, and materials. Further includes a list of applications of electrical equipment in aircraft with types of supply and power consumption of each.

**High-Potential Testing of Aircraft Equipment Electrical Insulation.** L. B. Kilman and J. P. Dallas. *Elec. Eng.*, June, 1956, pp. 540–544.

**Contact Arcing Factors to 100,000 Ft.** M. Raymond Alexy. *Elec. Mfg.*, June, 1956, pp. 141–144. Derivation of the altitude factor in air-borne component design from actual measurements, with graphs showing the effect of contact size and shape.

**Arc Suppression with Semiconductor Devices.** F. W. Parrish. *Elec. Mfg.*, June, 1956, pp. 127–131, 344, 346. Design procedures for contact-protection circuits using germanium or selenium rectifiers to reduce erosion from inductive kickback voltage. Includes curves for deriving the unknowns for the rectifier rating specifications.

**The Commutation Time of an Armature Coil, and the Stepforming Phenomena of a Commutation Curve.** Heinz Kluge. (*Elektrotech. Z., Ausg. A, 1955, pp. 802–806.*) *Gt. Brit., RAE Lib. Transl. 567*, Apr., 1956. 10 pp. Experimental results show that commutation depends on the type of brush material and the nature of the contact surface. Further tests show that steps in the short circuit current curve are caused either by the intermittent contact between brush and commutator or by the damping phenomena of the armature coils.

### *Hydraulic & Pneumatic*

**Electro-Hydraulic Servo-Valves.** *Appl. Hydraulics*, May, 1956, pp. 71–75. Application and general description of servovalves; includes detailed description of five different valves covering flapper-nozzle, internal pick-off, single-stage piston, pressure control, and two-stage with interval needle valves. Includes a glossary of servo terms.

## Fuels & Lubricants

**Comparative Studies of Methane and Propane as Engine Fuels.** N. P. W. Moore and B. N. Roy. *Chartered Mech. Engr.*, June, 1956, pp. 314–316. Abridged. Results of tests conducted in a Ricardo E.6 variable-compression-ratio engine to determine knock and auto-ignition characteristics.

**Fuels for Turbine Transports.** Hugh Harvey. *SAE J.*, June, 1956, pp. 55–59. Discussion of fuel characteristics with emphasis on stability under higher temperatures, fire hazard, low-temperature operation, and the problem of water in fuel.

## Instruments

**High Sensitivity Ballistic Fluxmeter.** A. V. Pohm and Sidney M. Rubens. *Rev. Sci. Instr.*, May, 1956, pp. 306–308. USAF-sponsored description of a quasi-static method in which a closed switch completes the circuit between the search coil and the galvanometer coil and the galvanometer is overdamped while the flux is changing in the specimen. The switch opens on completion of the flux change, and, upon subjection to critical damping, the galvanometer deflects like a normal charge-measuring instrument. The instrument is particularly applicable to materials characterized by a quasi-rectangular hysteresis loop.

**Development of a Vibrating-Coil Magnetometer.** D. O. Smith. *Rev. Sci. Instr.*, May, 1956, pp. 261–268. USAF-Army-Navy-sponsored description of an instrument to give a continuous measurement which can be recorded on a chart as a function of time, temperature, crystallographic orientation, or magnetizing field of a small sample of magnetic material placed in an external magnetizing field, by converting the dipole field of the sample into an a.c. electrical signal.

**Designing a Simulated Rate of Climb Indicator.** Rolf W. Neunes and Peter K. Stein. *ISA J.*, June, 1956, pp. 197–200. Description of an instrument to suit conditions including an altitude range from sea level to 70,000 ft., rates of climb from 500 to 50,000 ft./min., and a test-chamber volume of approximately 4,300 ft.³

**Wide Band Instrumentation.** Raymond L. Strazzulla. *IRE Trans., ANE Ser.*, June, 1956, pp. 74–83. Description of a mixer which is capable of handling both long- and short-time data with a high degree of stability and which rejects inaccurate input data to produce an output of high accuracy in both high- and low-frequency ranges.

### *Accelerometers*

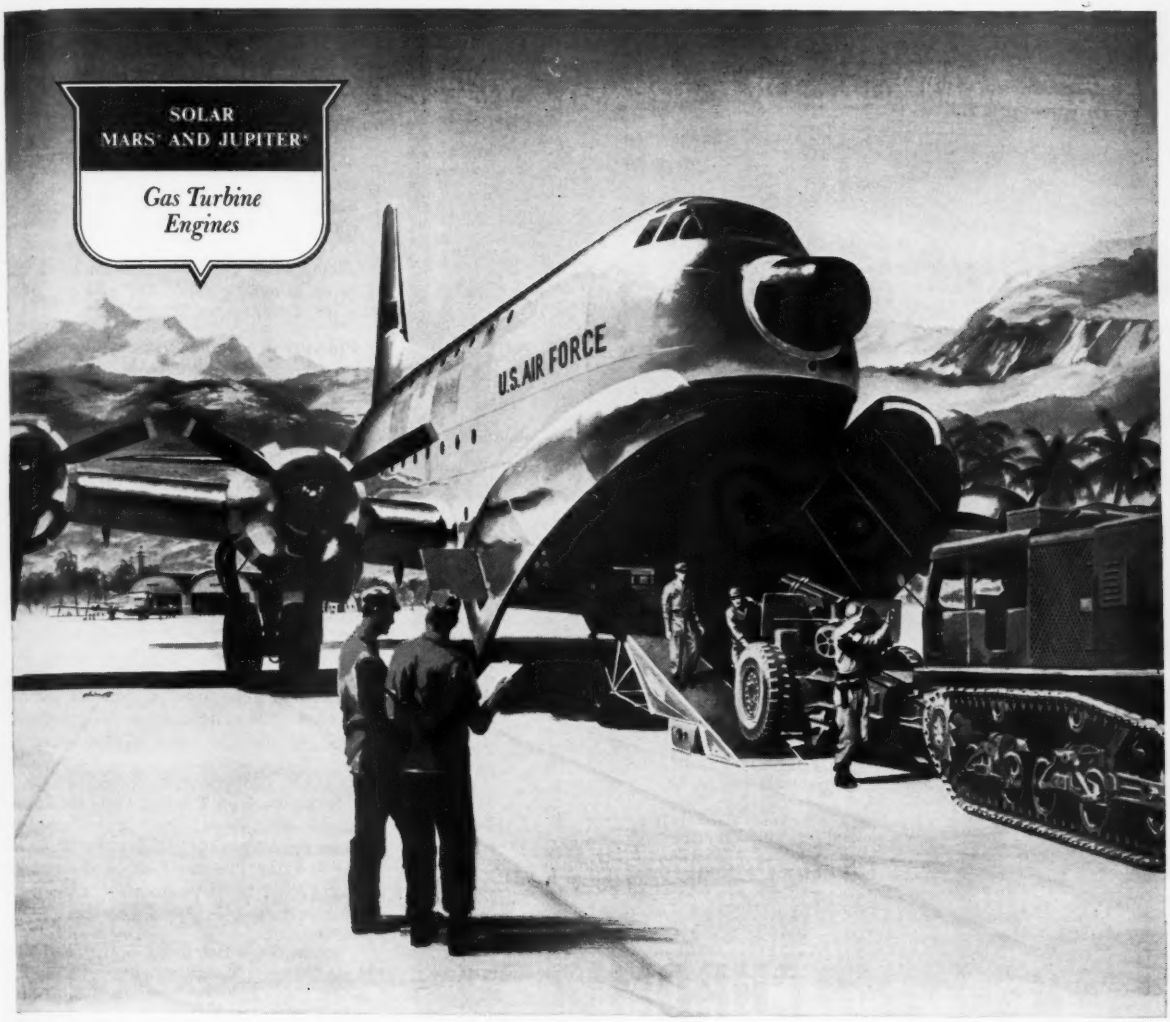
**Transit-Time Accelerometer.** L. M. Jones. *Rev. Sci. Instr.*, June, 1956, pp. 374–377. Description of an omnidirectional device developed to measure the drag acceleration of spheres dropped from rockets, from which the ambient density and temperature of air may be calculated.

### *Automatic Control*

**Optimalizing Control in the Presence of Noise Interference.** Sedat Serdengecti. *Jet Propulsion*, June, 1956, pp. 465–473. Discussion of a procedure for the detection of a modified peak-holding control system in order to determine its position in the optimum or its correct mode of operation.

**A Basic Outline of Servo Mathematics.** J. M. Nightingale. *Mach. Des.*, June 28, 1956, pp. 74–81. Summary of mathematical techniques based on differential equation analysis and used in the investigation of control-system performance.

**Servo Series. V—Designing Servos by the Phase-Plane Method.** Ira Ritow

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### *Flow Measuring Devices*

**Anémoclinométrie à Fils Chauds.** J. Gaudfernau. *La Recherche Aéronautique*, Nov.-Dec., 1955, pp. 15–22. 11 refs. In French. Analysis of the theory of hot-wire anemometry in terms of the translation of flow characteristics into electrical terms and of the derivation of correction factors. Description of the ONERA equipment designed for producing brief gusts and for studying the surge in axial compressors and the spectrum of transverse turbulence.

### *Pressure Measuring Devices*

**Sondes de Pressions Moyennes.** L. Viaud. *La Recherche Aéronautique*, Nov.-Dec., 1955, pp. 23–26. In French. Description of an averaging probe in which several probe tubes are mounted on a profiled cylinder and the mean pressure is recorded by a single manometer.

### *Recording Devices*

**Transistor Modulator for Airborne Recording.** Jay L. Upham, Jr., and Abraham I. Dranetz. *Electronics*, June, 1956, pp. 166–169. Development of a recording and telemetering system using a differential transformer transducer to provide phase and pulse time modulation for recording accelerations up to 180g and 500 cps.

### *Stress & Strain Measuring Devices*

**Some Work on Tension Pads for Structural Tests. Appendix I—The Method of Bonding Sorbo Rubber Tension Pads to the Loading Plates.** J. K. Oaks and P. B. Hovell. *Gt. Brit., ARC CP 238* (Aug., 1955), 1956. 15 pp. BIS, New York. $0.45.

**Strain Gage Balancing Simplifies Multiple-Bridge Measurements.** Peter K. Stein. *Prod. Eng.*, June, 1956, pp. 161–163. Design details for single-arm balancing networks to give uniform zero-strain reading. Applicable to available and new bridges.

### *Temperature Measuring Devices*

**On the Dynamic Temperature Response of a Vacuum Calorimeter.** J. S. Kouvel. *J. Appl. Phys.*, June, 1956, pp. 639–642. USAF - Army - Navy - supported development of a method for computing the heat capacity of a specimen in a vacuum calorimeter system from the temperature response in the after-heating period.

**Simplification of Airborne Navigation by Use of the Vortex Thermometer.** Robert E. Ruskin. *IRE Trans., ANE Ser.*, June, 1956, pp. 71–74. 10 refs. Description of an instrument for the direct measurement of true free-air temperature which elminates the corrections otherwise needed for dynamic heating caused by airplane velocity and which, when equipped with a linear resistance-temperature element, permits the use of a linear potentiometer in a simple digital null-balancing servo.

## Machine Elements

**Factors Affecting Oil-Groove Design in Bearings.** S. Kyropoulos. *Mach. Des.*,

June 14, 1956, pp. 119–122. Consideration of unidirectional and rotating loads, oil flow requirements, permissible bearing loads, position of oil inlet, and axial versus circumferential grooving.

**On the Integration of Reynolds Equation for Journal Bearings of Finite Width.** G. Vogelpohl. (*Ing.-Arch.*, No. 14, 1943, pp. 192–212.) *Gt. Brit., MOS TIB/T4578*, Feb., 1956. 29 pp. 18 refs. Translation.

**Bending Stresses in Spur Gear Teeth: Proposed New Design Factors Based on a Photo-Elastic Investigation.** M. A. Jacobson. *IME Proc.*, No. 33, 1955, pp. 587–604; Communications, pp. 605, 606; Author's reply, pp. 607–609. 23 refs.

**On the Maximum and Minimum Velocities and the Accelerations in Four-Link Mechanisms.** Ferdinand Freudenstein. *Trans. ASME*, May, 1956, pp. 779–785; Discussion, pp. 786, 787.

**Analysis of Creep in Rotating Disks Based on the Tresca Criterion and Associated Flow Rule.** A. M. Wahl. *J. Appl. Mech.*, June, 1956, pp. 231–238. Application of the Tresca criterion and the associated flow rule to the problems of calculating creep deformations and stresses in rotating discs at elevated temperatures.

## Materials

### *Corrosion & Protective Coatings*

**Basic Design Principles and Practices in Selecting Corrosion-Resistant Structural Materials.** Howard T. Francis. *Mach. Des.*, May 31, 1956, pp. 104–107.

**Corrosion and Stress Corrosion Properties of Aluminium-Copper and Aluminium-Copper-Cadmium Alloys.** C. Braithwaite. *Gt. Brit., RAE TN Met. 219*, Nov., 1955. 9 pp. Investigation of the corrosion resistance with and without stress.

**Floor and Fuselage Corrosion.** *Douglas Serv.*, May-June, 1956, pp. 1–16. Evaluation of design improvements for preventing corrosion and suggestion of maintenance procedures.

### *Metals & Alloys*

**A Dictionary of Metallurgy. XLIII—Si-So; XLIV—So-Sp.** A. D. Merriman and J. S. Bowden. *Metal Treatment*, May, June, 1956, pp. 185–192, 225–232.

**A Reconciliation of Certain Recovery Properties in Metals.** A. J. Kennedy. *J. Mech. & Phys. Solids*, May, 1956, pp. 162–166. 18 refs. Method of expressing mechanical and electrical properties of metals with similar time and temperature functions using recovery properties of metals as an example.

**Effect of Crack Length and Stress Amplitude on Growth of Fatigue Cracks.** Waloddi Weibull. *Sweden, Flygtekniska Försöksanstalten, FFA Medd. 65*, 1956. 44 pp. Investigation of fatigue cracks using notched specimens of Unclad 24 S-T and Alclad 75 S-T done with nearly constant stress amplitudes obtained by reducing the load in proportion to the remaining area.

**Fatigue Tests on Material to Specification B.A.C.E. 54 (D.T.D. 551).** P. H. Frith. *Gt. Brit., MOS S&T Memo.* 16/55, Oct. 18, 1954. 18 pp. Results of tests on an alloyed steel specimen to determine its properties with relation to aircraft engine crankshafts. Tests were carried out with reversed bending, reversed torsional stresses, and various combinations of bending and torsional stresses, using solid and hollow specimens with a transverse oil hole, with and without nitriding.

**Materials for High Temperatures.** C. L. Clark. *Mach. Des.*, May 31, 1956, pp. 95–98. Discussion of requirements for high-temperature materials in power generation equipment, gas turbines, and aircraft and missile structures.

### *Metals & Alloys, Nonferrous*

**Light Alloys.** P. D. Frost. *Mach. Des.*, May 31, 1956, pp. 86–89. Review of developments and applications of aluminum, magnesium, and titanium and suggestions of problems to be solved by future research.

**Creep of Aluminum Single Crystals.** J. Weertman. *J. Appl. Phys.*, July, 1956, pp. 832–834. 10 refs. Measurements taken over the stress range of $2.5 \times 10^6$ to $1.9 \times 10^8$ dynes/cm.$^2$ and over the temperature range of 157°C. to 616°C., in order to provide data for testing high-temperature creep theories.

**Comparison of Theoretical and Experimental Results for 24 S-T and 75 S-T Aluminium Alloy Columns Buckling in the Elastic and Inelastic Ranges.** Bo Braathen and Bryan R. Noton. *Sweden, Flygtekniska Försöksanstalten, FFA Medd. 66*, 1956. 31 pp. 12 refs. Theoretical and experimental investigation of elastic and inelastic buckling in columns. Specimens tested include 150 aluminum columns, 17 pin-ended and 133 flat-ended.

**Effect of Two Types of Etching Pencil Marking on the Fatigue Strength of Aluminium Alloy DTD 683.** J. T. Ballet. *Gt. Brit., RAE TN Met. 232*, Nov., 1955. 7 pp.

**The Tearing of Aluminium Foils.** J. Hennephof. *J. Mech. & Phys. Solids*, May, 1956, pp. 172–183. Study of the propagation of cracks in ductile materials, taking into account the tearing force and the tearing energy.

**The Current Efficiencies of Electro-Deposition of Metallic Titanium in Fusion Electrolysis.** S. Okada, M. Kawane, and M. Takahashi. (*Kyoto U. Eng. Res. Inst. Bul.*, 1954, pp. 57–60.) *Gt. Brit., MOS TIB/T4596*, Mar., 1956. 5 pp. Translation.

**Tools and Methods for Forming Titanium.** James S. Kirkpatrick. *Tool Engr.*, June, 1956, pp. 85–89. Abridged. Discussion of forming techniques such as stamping, hot drawing, hot rubber forming, spinning, and machining.

**How to Heat Treat Titanium.** Walter L. Finlay, W. W. Wentz, and D. W. Kaufmann. *Materials & Methods*, June, 1956, pp. 126–131. Discussion of the effects of heat treatment on mechanical properties of titanium. Includes a description of crystal lattice structure and a time-temperature chart.

**The Structural Damping of Titanium at Elevated Temperature.** H. F. Hunter. *Aero. Eng. Rev.*, Aug., 1956, pp. 18–21. Experimental investigation using a heated tuning fork, with results expressed in terms of the logarithmic decrement of the decaying oscillation. Includes calculation of the dynamic modulus-of-elasticity variation from ratios of measured frequencies.

**Mechanical Properties of Ti 75A Sheet Titanium at Room and Elevated Temperatures.** D. C. Hayward. *Gt. Brit., RAE TN Met. 210*, Nov., 1955. 20 pp. Measurement in both tension and compression of the Young modulus, tangent modulus, secant modulus, and 0.1, 0.2, and 0.5 per cent proof-stresses; includes results of maximum stress and per cent elongation presented in graphical form for tension only.

**What's Titanium's Future in Aircraft Hydraulic Circuits?** Don F. Collins. *Appl. Hydraulics*, May, 1956, pp. 124, 126, 128. Investigation of titanium for hydraulic systems at high temperatures. Impulse, vibration, and assembly tests were run comparing fittings and tubing of aluminum, stainless steel, and titanium.

### *Nonmetallic Materials*

**Some Dynamic Mechanical Properties of Heat-Treated Low-Alloy Weld Deposits.** E. H. Franks and W. H. Wooding. *Welding J. Res. Suppl.*, June, 1956, pp. 291-s–297-s. Experimental investigation of the impact and fatigue strengths of nickel-molybdenum-vanadium deposits in the as-welded, stress-relieved, quenched, tempered, and annealed conditions.

**High-Strength Adhesives for Metal Bonding.** R. F. Blomquist. *Mach. Des.*, May 31, 1956, pp. 99–103. 19 refs. Discussion includes types of metal-bonding adhesives, description of the bonding process, design considerations, and future trends in bonding.

**The Assessment of Interlaminar Strength in Shear of Polyester-Glass Laminates.** R. B. King. *Gt. Brit., RAE TN Chem. 1258*, Aug., 1955. 9 pp. Development of a method to estimate interlaminar shear strength, taking into account the effects of degree of cure, surface treatment, and humidity.

**Propriétés Mécaniques des Fils de Verre Utilisés dans les Stratifiés.** A.-Kh. Iablokoff. *La Recherche Aéronautique*, Nov.-Dec., 1955, pp. 39–49. In French. Results of tests of rupture strength and tensile modulus of continuous filament yarn presented as a tentative explanation of discrepancies between theoretical values and those obtained in laminates.

**Development of Expanded Resins for Aircraft Applications.** J. L. Chinn. *Auto. Ind.*, July 1, 1956, pp. 48, 49, 112. Discussion of uses for expanded or foamed-in-place resins as bulk fillers and potted compounds in aircraft components.

**Reinforced Plastics in Aircraft and Guided Missiles.** William E. Braham. *SPE J.*, June, 1956, pp. 87, 88. Application of reinforced plastics to aircraft parts and components, including fuel tanks, rocket pods, compressor blades, and radar parts.

**Plastics for Structural Uses.** *Prod. Eng.*, June, 1956, pp. 167–182. Description and classification in terms of design requirements such as chemical and temperature resistance, mechanical properties, dimensional stability, and production methods.

**Processing Makes the Plastic.** W. Crofut and L. B. Keller. *SAE J.*, May, 1956, pp. 64–69. Discussion covering seven methods, their applications, and examples of typical component manufacturing problems. Methods include: transfer-, compression-, and injection-molding; injection-molding using a specially formulated material; low-pressure reinforced lamination; high-pressure molded lamination; and metal fabrication for the production of missile parts.

**The Mechanics of High Polymers.** Yoh-Han Pao and Werner Brandt. *Appl. Mech. Rev.*, June, 1956, pp. 233–236. 32 refs. Derivation of equations for small deformations of viscoelastic solids and for large deformations of viscoelastic liquids.

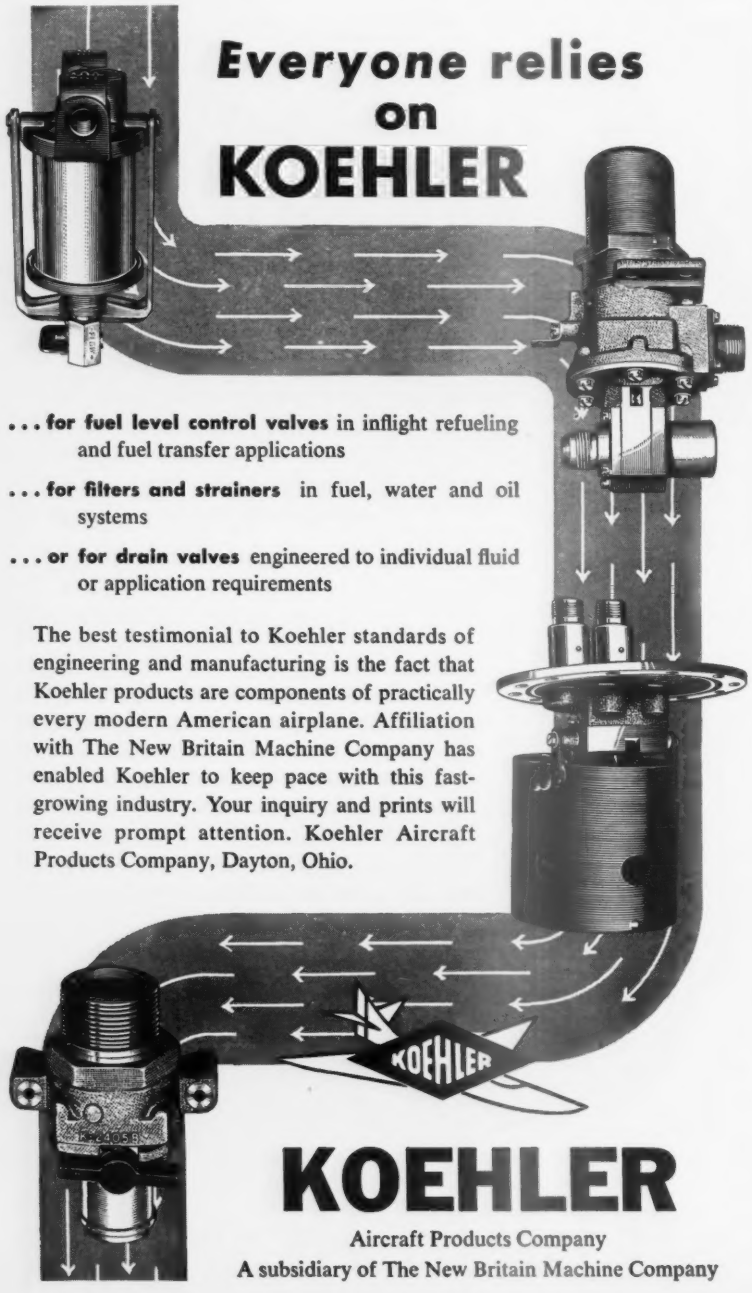
**Special Issue on Rheology of Polymers; Stress Analysis in Viscoelastic Materials.** E. H. Lee. *J. Appl. Phys.*, July, 1956, pp. 665–672. 22 refs. Theoretical investigation of three basic aspects of the problem of stress analysis—measurement of material properties, derivation from these of the operator equations between stress and strain or equivalently of the viscoelastic model, and use of these equations in theoretical stress analysis. Includes a discussion of the quasi-static analysis in which inertia forces are general, and consideration of a series of typical solutions to wave problems that arise at the inclusion of inertia effects and which are restricted to one-dimensional space variations.

**Polyethylene—Past and Future.** G. W. Jargstorff and G. F. Kirkpatrick. *SPE J.*, June, 1956, pp. 25–27. Discussion of physical properties and indication of possible applications.

**Associated Problems in Two-Dimensional Elasticity.** J. E. Adkins. *J. Mech. & Phys. Solids*, May, 1956, pp. 199–205. Method for the simultaneous solution of two or more problems with analytically similar boundary conditions in two-dimensional elasticity.

**Finite Plane Deformation of Thin Elastic Sheets Reinforced with Inextensible Cords.** J. E. Adkins. *Philos. Trans. Royal Soc. (London), Ser. A*, May 31, 1956, pp. 125–150. 12 refs. Derivation of a general theory for the finite elastic deformation of curvilinearly aeolotropic materials subject to restraints, applied to a thin, plane, uniform sheet of elastic material reinforced by means of a continuous layer of thin, flexible, inextensible cords.

**Properties and Applications of Silicone Rubber.** S. A. Braley, Jr. *ASME Semi-Annual Meeting, Cleveland, June 17–21, 1956, Paper 56–SA–53.* 5 pp. Comparison of properties and applications of silicone rubber with those of organic rubber, with emphasis on the behavior of the two materials at high and low temperatures. The physiological inertness of silicone rubber, its dielectric properties, and its resistance to various chemicals and oils are also discussed.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## Mathematics

**Über homogene lineare Ungleichungssysteme.** E. Burger. *ZAMM*, Mar.-Apr., 1956, pp. 135–139. In German. Description of a method for solving a homogeneous linear inequation system which is based on the hypothesis that a simple explanation of the changes in the solving cone of such a system may be derived by addition of a supplementary inequation.

**A General Sphere Theorem for Hydrodynamics, Heat, Magnetism, and Electrostatics.** G. C. K. Yeh, J. Martinek, and G. S. S. Ludford. *ZAMM*, Mar.-Apr., 1956, pp. 111–116.

**On a Regular Cauchy Problem for the Euler-Poisson-Darboux Equation.** E. T. Copson. *Proc. Royal Soc. (London), Ser. A*, June 12, 1956, pp. 560–572.

**Beitrag zu Walls Verfahren der getrennten Berechnung von Real- und Imaginärteilen der Nullstellen eines Polynoms.** Luiz Occhini. *ZAMM*, Mar.-Apr., 1956, pp. 139–145. In German. Description of a method for the separate determination of real and imaginary parts of the zeros of a given polynomial, which retains the advantages of the Wall method and permits the carrying out of the interpolation by means of the value of a polynomial. The method is particularly applicable for use with sequence-controlled digital computers.

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*Jet & Turbine*

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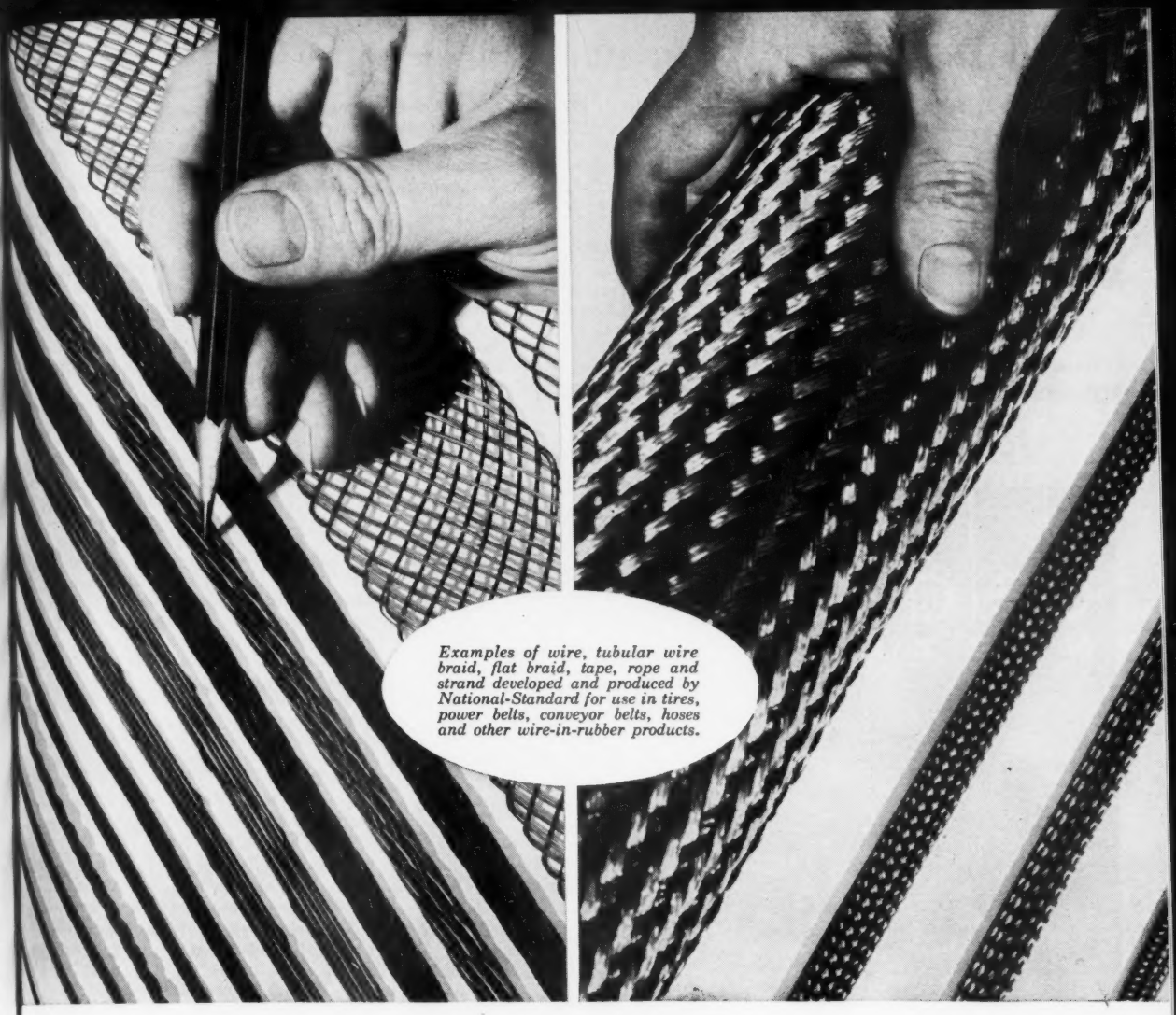

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## Space Travel

**A Research Program Based on the Optical Tracking of Artificial Earth Satellites.** F. L. Whipple and J. A. Hynek. *Proc. IRE*, June, 1956, pp. 760–764. Discussion of the problems involved in early acquisition tracking, frequent orbit calculations, ephemeris predictions for the precise photographic tracking, the establishment and operation of 12 to 15 precision photographic stations over the earth, operation of a communication net, and both current and final analysis of the positional data for obtaining more precise geophysical results.

**Tracking the Earth Satellite, and Data Transmission, by Radio.** John T. Mengel. *Proc. IRE*, June, 1956, pp. 755–760. Description of the NRL-developed Minitrack system which is independent of time, weather, or seeing conditions for acquisition and tracking of the satellite by radio techniques, with a discussion of probable tracking accuracies.

**Telemetering and Propagation Problems of Placing the Earth Satellite in Its Orbit.** Daniel G. Mazur. *Proc. IRE*, June, 1956, pp. 752–754.

**Placing the Satellite in Its Orbit.** Milton W. Rosen. *Proc. IRE*, June, 1956, pp. 748–751. Discussion of the method of launching and explanation of the reasons for selecting the adopted method.

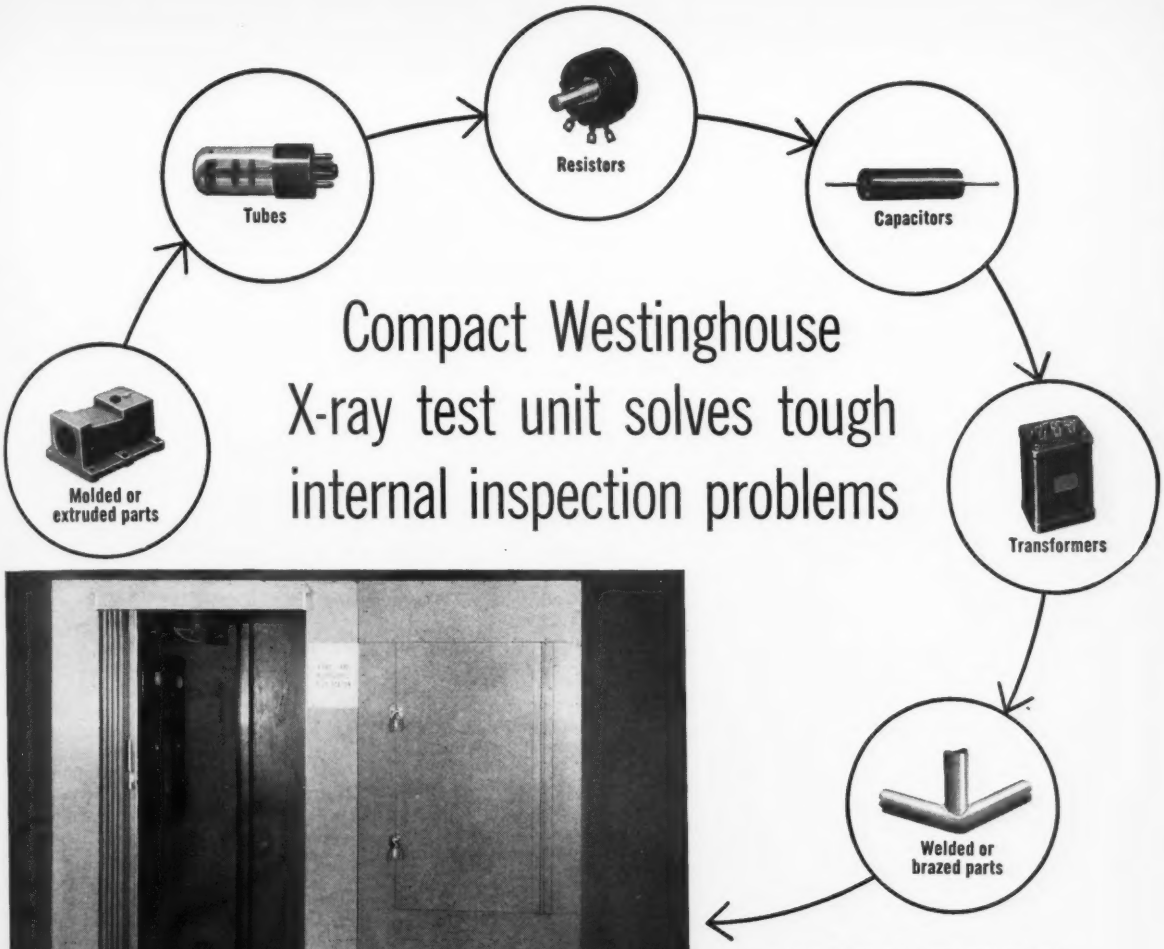
## Structures

**Aircraft Structures Must Fail Safe.** J. F. McBrearty. *SAE J.*, June, 1956, pp. 26, 27, 29. Comparison between the safe-life and fail-safe methods of structural design showing advantages of the latter method.

**Tear Resistance in Aircraft Structures.** J. Anthony Edwards. *Aeronautics*, June, 1956, pp. 71, 73, 74, 77. Description of investigations of crack propagation covering fuselage tear, cyclic pressure, and puncture tests.

**The Influence of Pre-Loading on the Fatigue Life of Aircraft Components and Structures.** Appendix I—**Fatigue Tests on D.T.D.546 B Aluminium Alloy Sheet Specimens.** Appendix II—**Fatigue Tests on Lugs.** Appendix III—**Fatigue Tests on Channel-Sectioned Parts.** Appendix IV—**Fatigue Tests on Transverse Hole Specimens.** Appendix V—**Fatigue Tests on Wing Joints.** Appendix VI—**Fatigue Tests on Meteor 4 Tailplanes.** Appendix VII—**Fatigue Tests on (a) Circumferentially Notched Specimens, and (b) Spot Welded Joints.** R. B. Heywood. *Gt. Brit., ARC CP 232*, 1956. 27 pp. BIS, New York, $0.72. Results of fatigue tests on aircraft components and structures show that the tensile preloading increases fatigue life and that the compressive preloading reduces fatigue life. This phenomenon is attributed to residual stresses and to load redistributions induced by preloading.

**The Strength of Tubes Under Uniform External Pressure.** P. C. Cleaver. *Gt.*

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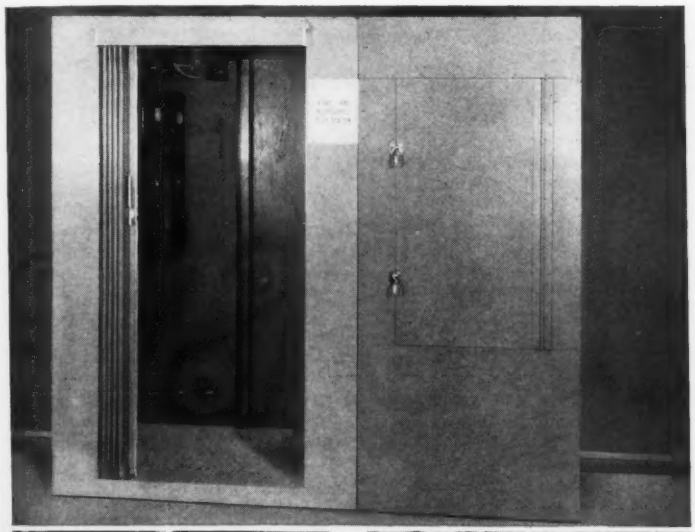

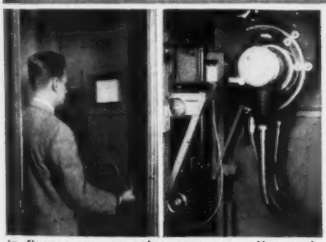

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*Brit., RAE Rep. Struc. 193*, Nov., 1955. 180 pp. 29 refs. Evaluation of the development of theoretical solutions to the problem of determining the strength of tubes subjected to uniform external pressure, and description of an extensive series of tests to check the accuracy of the Sturm solution to this problem and the effects of material properties on collapse pressure. A total of 530 tests were made covering ranges of length-to-diameter from 14.0 to 0.51 and nominal thickness-to-diameter from 0.0098 to 0.056.

**Remarks on the Centre of Shear.** Carl E. Pearson. *ZAMM*, Mar.-Apr., 1956, pp. 94–96. Analysis of the discrepancy between the methods for calculating the position of the center of shear in order to determine the limits for the quantity of the difference.

**Stiffness of Curved Circular Tubes with Internal Pressure.** P. G. Kafka and M. B. Dunn. *J. Appl. Mech.*, June, 1956, pp. 247–254. 12 refs. Method for computing the flexibility factor for plane pipe lines considering internal-pressure effects. Formulas for the first and second approximation to both the flexibility and the stress-intensification factors are given.

**On Thin-Ring Analysis.** Bruno A. Boley. *J. Aero. Sci.*, Aug., 1956, pp. 802–804. Analysis giving a formula for the bending moment at any point of a closed ring of arbitrary shape under arbitrary loadings in the plane of the wing.

### *Bars & Rods*

**The Pattern of Plastic Deformation in a Deeply Notched Bar with Semicircular Roots.** L. Garr, E. H. Lee, and A. J. Wang. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 56–58. Analysis of finite deformation by a graphical method using a grid square scribed on the undeformed cross section. The deformed pattern shows regions of large plastic strain.

**The Nonlinear Bending of Thin Circular Rods.** H. D. Conway. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 7–10. Development of bending equations from the Bernoulli-Euler equation, taking into account both vertical and horizontal loading. Numerical results are plotted.

### *Beams & Columns*

**Buckling of Columns in the Presence of Creep.** Sharad A. Patel. *Aero. Quart.*, May, 1956, pp. 125–134. Application of the Hoff theory of creep buckling which takes into account the instantaneous elastic and plastic deformations and the transient and secondary creep phenomena.

**Creep Stresses and Deflections of Columns.** T. H. Lin. *J. Appl. Mech.*, June, 1956, pp. 214–218. 15 refs. Development of a direct method with no iteration for calculating stresses and deflections of a pin-ended column. The relaxation moment in a particular time interval is treated as an initial curvature of the column.

**Correlation of Creep-Buckling Tests with Theory.** Sharad A. Patel, Joseph Kempner, Burton Erickson, and Abol H. Mobassery. *U.S., NACA RM 56C20*, May 23, 1956. 39 pp. 11 refs. Results of short-time creep-buckling and creep-bending tests of 2024-T4 aluminum-alloy columns of slenderness ratio 111. The results are used in combination with a previously derived creep-buckling theory for the derivation of a semiempirical formula applicable as a guide to the determination of the critical time for columns.

**A Method of Stepwise Integration in Problems of Impact Buckling.** A. F. Schmitt. *J. Appl. Mech.*, June, 1956, pp. 291–294. Method for the calculation of approximate load and deflection variations for an axially impacted column, when the high-velocity impact stresses exceed the elastic limit.

**Plastic Deformation of Semi-Infinite Beams Subject to Transverse Impact Loading at the Free End.** M. F. Conroy. *J. Appl. Mech.*, June, 1956, pp. 239–243. Analysis of semi-infinite beams subjected to a constant bending moment, together with a transverse force which is proportional to the square root of time. Solutions are presented for the plastic-rigid and for the elastic-plastic cases.

**Pretwisted Beams and Columns.** John Zickel. *J. Appl. Mech.*, June, 1956, pp. 165–175. Development of a theory for the behavior of pretwisted structural members of a thin-walled section with slight initial bending.

**Some Solutions of the Timoshenko Beam Equations.** B. A. Boley and C. C. Chao. (*ASME Natl. Conf., Troy, N.Y., June 16–18, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 579–586. Application of the method of Laplace transformation to the solution of four types of loading applied to a semi-infinite beam.

### *Cylinders & Shells*

**Analysis of Short Thin Axisymmetrical Shells Under Axisymmetrical Edge Loading.** G. Horvay, C. Linkous, and J. S. Born. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 68–72. 13 refs. Based on work by Hildebrand on modification of the Geckeler method to embrace shells of short length with slowly varying meridional curvature and wall thickness. Resulting formulas are suited for the analysis of the tapered hub portion of a flanged shell.

**Displacements in an Elastic-Plastic Cylindrical Shell.** P. G. Hodge, Jr. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 73–79. The elastic-plastic problem is stated for an ideal sandwich shell, and the stresses and deformations are computed for a particular example. An approximate technique, applicable to all shells, is developed in order to replace laborious computations.

**Deformations of an Elastic-Plastic Cylindrical Shell with Linear Strain Hardening.** P. G. Hodge, Jr., and F. Romano. *J. Mech. & Phys. Solids*, May, 1956, pp. 145–161. Analysis of a thin-walled cylindrical shell of finite length subjected to a slowly increasing uniform radial pressure, taking into account linear strain hardening.

**Thin Circular Conical Shells Under Arbitrary Loads.** N. J. Hoff. (*ASME Natl. Conf., Troy, N.Y., June 16–18, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 557–562. Derivation of three partial differential equations through the use of variational calculus to define the displacement of the median surface of a conical shell.

**Stress Distributions Within Solids Bounded by One or Two Cones.** Antony J. A. Morgan. *ZAMP*, Mar. 25, 1956, pp. 130–145. Derivation of a formal solution, using the Mellin transform, of the governing differential equation for the stress functions in the case where the solid is subjected to axially symmetric external loadings. Includes an illustrative example of the semi-infinite solid cone.

**Bending and Torsion of Circular Cylinder Cantilever Beams of Cylindrically Aeolotropic Material.** W. S. Ericksen. *J. Appl. Mech.*, June, 1956, pp. 185–190. Analysis for the determination of stress components and displacements of cantilever beams using the Saint Venant semi-inverse method.

**On Axially Symmetric Bending of Nearly Cylindrical Shells of Revolution.** R. A. Clark and E. Reissner. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 59–67. Method for obtaining approximate solutions for stresses and deflections by means of a perturbation process based on the assumption that all desired quantities can be represented as expansions in powers of two small parameters. This procedure in turn leads to a set of linear differential equations with constant coefficients, which may be solved successively.

**Elastic-Stress Waves Produced by Pressure Loads on a Spherical Shell.** J. H. Huth and J. D. Cole. (*ASME West Coast Conf., Monterey, Sept. 12, 13, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 473–478. Analysis of the problem of stresses in a spherical elastic shell as related to the study of the effect of blast waves on a missile in flight.

### *Elasticity & Plasticity*

**Bending Creep and Its Application to Beam-Columns.** L. W. Hu and N. H. Triner. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 35–42. 11 refs. Development of a method for determining the creep deflection of a member subjected to a bending moment, and its application to a beam column. Results of experimental verification conducted on a beam-column of FS1-F magnesium alloy at 260° F. compared satisfactorily with theoretical predictions.

**Relative Accuracy of Deflections and Bending Moments (or Stresses) Derived by the Method of R.A.E. Report No. Structures 168.** D. Williams. *Gt. Brit., RAE TN Struc. 188*, Mar., 1956. 12 pp.

**Combined Stress Tests in Plasticity.** Aris Phillips and Lloyd Kaechele. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 43–48. 10 refs. Results of tests on thin-walled tubes of 2S-O aluminum alloy, where in most tests the tubes were subjected to combined tension and torsion with variable stress ratios. Results favor incremental theories of plasticity.

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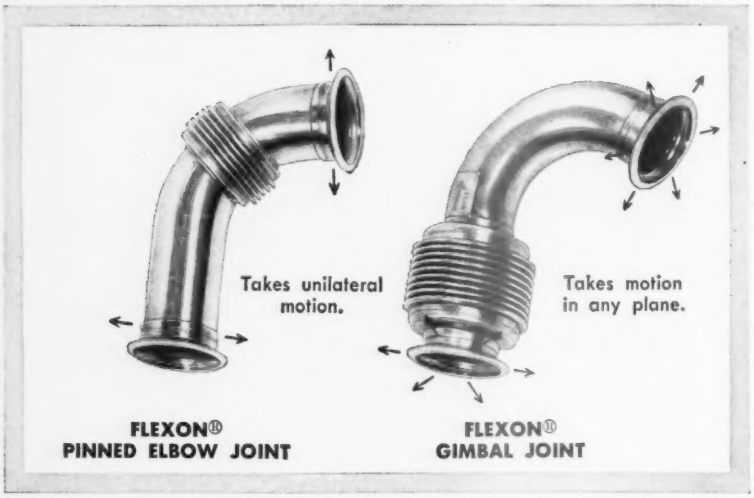


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**Das ungelöste Hauptproblem der endlichen Elastizitätstheorie.** C. Truesdell. *ZAMM*, Mar.-Apr., 1956, pp. 97–110. In German. Summary of investigations in the finite theory of elasticity.

**Linear Superposition in Visco-Elasticity and Theories of Delayed Effects.** E. R. Love. *Australian J. Phys.*, Mar., 1956, pp. 1–12. Establishment of necessary and sufficient conditions, expressed in physical and mathematical terms, for the formula expressing the stress history as an integral linearly involving the strain history.

**Plastic Deformations of a Free Ring Under Concentrated Dynamic Loading.** R. H. Owens and P. S. Symonds. (*ASME Natl. Conf., Troy, N.Y., June 16–18, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 523–529. Analysis of concentrated time-dependent forces acting along a diameter on an unsupported ring to obtain approximations of the deformation of the ring by neglecting elastic strain and by assuming ideally plastic behavior.

**The Stress Distribution in a Strip Loaded in Tension by Means of a Central Pin.** P. S. Theocaris. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 85–90. Derivation of an exact solution for the stress distribution in a strip of infinite length having a single axial hole. An alternating approximation method is used to determine the stress distribution, and the stresses are tabulated in the form of stress-concentration factors for different values of diameter of the hole.

**Stress Waves in Solids.** R. M. Davies. *Brit. J. Appl. Phys.*, June, 1956, pp. 203–209. Elementary discussion of the transmission of transient stress pulses of short duration and of the problem of measuring pressures subject to rapid changes, with detailed description and evaluation of the pressure bar method. Includes consideration of the changes in form of stress wave pulses as they recede from the origin and of the main features of distortion when the pulses are propagated in elastic and viscoelastic solids and in solids stressed beyond the elastic limit.

**Stress Concentration Caused by Multiple Punches and Cracks.** Michael Sadowsky. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 80–84. 10 refs. General theory of stress distribution under several punches in simultaneous action and of stress concentration caused by several cracks. A complete evaluation for the case of two punches or two cracks is included.

**The Affine Transformation for Orthotropic Plane-Stress and Plane-Strain Problems.** H. A. Lang. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 1–6. Extension of the isotropic plane problem to the solution of orthotropic plane problems by use of a single affine transformation of the type $x = ax'$, $y = by'$, where the orthotropic material is characterized by three independent constants instead of the normal four independent constants.

**Über ein simultanes Differenzenverfahren zur Abschätzung der Torsionssteifigkeit und der Kapazität nach beiden Seiten.** Joseph Hersch, Albert Pfluger,

and Andreas Schopf. *ZAMP*, Mar. 25, 1956, pp. 89–113. In German. Derivation of a theoretical method of determining the upper and lower bounds of the torsion of a prism whose cross section is covered by a mesh lattice, taking into account Thompson and Dirichlet principles.

**Comparison of Slip-Line Solutions with Experiment.** E. G. Thomsen. *J. Appl. Mech.*, June, 1956, pp. 225–230. 13 refs. Plane-strain and axially symmetric approximate solutions for perfect plasticity are compared with experimental results obtained from the extrusion of a billet of commercially pure aluminum.

### *Plates*

**On Some Problems in Bending of Thick Circular Plates on an Elastic Foundation.** Daniel Frederick. *J. Appl. Mech.*, June, 1956, pp. 195–200. 10 refs. Solutions using the Reissner theory for the case of axially symmetric bending of a finite circular plate on an elastic foundation under a partial uniform loading, and of the case of nonsymmetric bending of an infinite plate on an elastic foundation with a rigid circular inclusion.

**Experimental Verification of Circular Plate Bending Theory.** Jacob Herrmann and C. S. Ades. *J. Franklin Inst.*, June, 1956, pp. 631–635. Experimental investigation involving two circular ring plates under a concentrated load along the inner edge and freely supported along the outer edge. Includes strain measurements taken at various radii of plates with both uniform and nonuniform profiles; tests on discs loaded to virtual failure, as indicated by excessive deflections, in order to determine their rupture factors; and a hardness check on the uniform plate to evaluate the ultimate tensile strength.

**Biegung dünner Platten und Variationssätze bei einem nichtlinearen Elastizitätsgesetz.** K. Özden. *Ing.-Arch.*, No. 3, 1956, pp. 133–147. In German. Study of the problem of bending of thin plates, with a development of three methods for the solution of basic equations of the theory of elasticity for small distortions.

**Buckling of Simply Supported Plates Tapered in Planform.** Bertram Klein. *J. Appl. Mech.*, June, 1956, pp. 207–213. Derivation of design curves for determining the elastic buckling loads of simply supported flat plates of isosceles trapezoidal plan form, loaded in compression along the parallel edges.

**Theory of Plastic Buckling of Plates and Application to Simply Supported Plates Subjected to Bending or Eccentric Compression in Their Plane.** P. P. Bijlaard. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 27–34. 27 refs. The solutions are based on the author's theory of plastic plate buckling and are obtained by reducing the governing partial differential equation to ordinary finite-difference equations. Second-order finite differences are used, with a spacing equal to one ninth of the plate width. A simple design formula is presented for the plastic reduction factor with which the elastic buckling stress must be multiplied in order to obtain the plastic buckling stress.

**Large Deflections of Elliptical Plates.** N. A. Weil and N. M. Newmark. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 21–26. 15 refs. Solution by the energy method of a changed elliptical plate of constant thickness and subjected to a uniformly distributed load. The treatment is extended to the limiting cases of the circular plate and infinite strip.

**A New Approach to the Analysis of Large Deflections of Plates.** Appendix—**Circular Plates with Uniform Loading.** H. M. Berger. (*ASME West Coast Conf., Monterey, Sept. 12, 13, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 465–472. 12 refs. Derivation of approximate simplified nonlinear equations, under the assumption that the strain energy due to the second invariant of the middle-surface strains can be neglected. Includes calculations for the deflection of uniformly loaded circular and rectangular plates with various boundary conditions and a comparison with available numerical solutions of the exact equations, using the obtained deflections for the calculation of stresses of a circular plate.

**Solution of the Problem of the Cantilever Square Plate by the Use of Influence Coefficients and a High Speed Digital Computer.** D. Williams and P. C. Birchall. *Gt. Brit., RAE TN Struc. 178 (M.S. 25)*, Mar., 1956. 6 pp. Solution for stresses and deflections of a square plate of constant thickness, fixed along one edge and subjected to transverse loads.

**On the Theory of Curved Plates with Pronounced Deformation.** K. Marguerre. (*5th Cong. Appl. Mech., Harvard U. and MIT, Sept. 12–16, 1938, Proc.*) *Gt. Brit., MOS TIB/T4613*, Mar., 1956. 16 pp. 11 refs. Translation. Analysis of the elastic behavior of curved plates beyond the stability limits using the energy method. Two equations for stress function and vertical displacement are obtained for the case of slight precurvature, and the Ritz method is used to obtain approximate solutions.

**Theoretical Determination of Rigidity Properties of Orthogonally Stiffened Plates.** N. J. Huffington, Jr. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 15–20. 15 refs. Analytical development of four effective rigidity constants in terms of elastic constants of the material and of plate geometry, which can be used for thin orthotropic plates in determining mean deflections and stresses of the stiffened plate.

**The Load-Carrying Capacity of Circular Plates at Large Deflection.** E. T. Onat and R. M. Haythornthwaite. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 49–55. 18 refs. Approximate analysis of load capacity (after finite deflection) by assuming a velocity field based on boundary conditions and on the incipient velocity field of the flat circular plate.

**Optimum Designs for Reinforced Circular Holes.** E. H. Mansfiel. *Gt. Brit., ARC CP 239*, 1956. 28 pp. BIS, New York. $0.72. Development of an optimum weight-strength design method for reinforced circular holes in an infinite sheet. It is shown that, for a given total weight of reinforcement, the stress concentration in the sheet may be reduced by suitably varying the reinforcement around the hole.

### *Sandwich Structures*

**End Grain Balsa as a Sandwich Core Material; A Study of the Properties of Wood Cored Panels Used in the Construction of Aircraft.** J. P. White. *Aircraft Eng.*, June, 1956, pp. 199–201.

**On the Torsion of Rectangular Sandwich Plates.** Paul Seide. *J. Appl. Mech.*, June, 1956, pp. 191–194. Calculation of the torsional rigidity of rectangular sandwich plates of constant thickness, assuming free-to-warp cross sections. The faces are isotropic and of equal thickness while the core may be orthotropic, the axes of orthotropy coinciding with coordinate axes of the structure.

### *Testing*

**The Application of Radiography to Airframe Inspection.** R. A. Fry and E. W. Kowol. *Aeronautics*, May, 1956, pp. 86, 89, 90.

**Techniques and Problems in Testing Structures at Elevated Temperatures.** Lewis H. Abraham. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 640.* 7 pp. Members, $0.35; nonmembers, $0.75. Discussion of testing methods and loading techniques for high-temperature testing of materials.

**Studies in Dynamic Photoelasticity.** M. M. Frocht and P. D. Flynn. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *J. Appl. Mech.*, Mar., 1956, pp. 116–122. 16 refs. Description of equipment and techniques used to obtain dynamic photoelastic stress patterns from arbitrary lines in plane-stress systems by mean of streak photography.

**Studies in the Theory and Application of Photoplasticity.** R. Hiltscher. (*VDI Zeitschrift*, No. 2, 1955, pp. 49–58.) *Gt. Brit., RAE Lib. Transl. 531*, Mar., 1956. 20 pp. Description of the method applied to the study of bodies exhibiting elastic and plastic strain, and of the growth of the plastic region and its effect on stress distribution in the elastic region for plane stress or strain states.

### *Thermal Stress*

**Theory and Experiment in the Solution of Structural Problems of Supersonic Aircraft. I—Aerodynamic Heating and Its Effects.** N. J. Hoff, Martin Bloom, Frederick V. Pohle, Henry Oliver, I. Mirsky, William I. Berks, and Alexander Chwick. **II—The Effect of Rapid Creep.** N. J. Hoff. **III—Theory and Practice of Induction Heating.** William R. MacLean and S. Lederman. *USAF WADC TR 55-291*, Mar., 1956. 346 pp.

**A Re-Evaluation of Some Airframe Thermal Problems.** Norris F. Dow. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 639.* 10 pp. 17 refs. Members, $0.35; nonmembers, $0.75. Discussion of material selection, thermal stresses, and creep in high-speed aircraft structures.

**An Engineering Approach to Some Structural Problems Arising from Kinetic Heating.** E. H. Bateman. *J. RAeS*, June, 1956, pp. 402–407. 10 refs.

**Large Deflection Analysis for a Plate Strip Subjected to Normal Pressure and Heating.** M. L. Williams. (*ASME West Coast Conf., Monterey, Sept. 12, 13, 1955.*) *J. Appl. Mech.*, Dec., 1955, pp. 458–464. Development of a single relation for calculating the deflection and membrane stress for an infinite strip with the end points fixed in space, with calculations for the specific cases of both clamped and simply supported plates subjected to a uniform pressure and uniform temperature rise.

**Panels Under Thermal Stress; The Behaviour of a Panel Restrained Against Expansion in One Direction and Loaded in the Other Direction When Subjected to Kinetic Heating.** E. W. Parkes. *Aircraft Eng.*, June, 1956, pp. 180–186.

## Thermodynamics

### *Combustion*

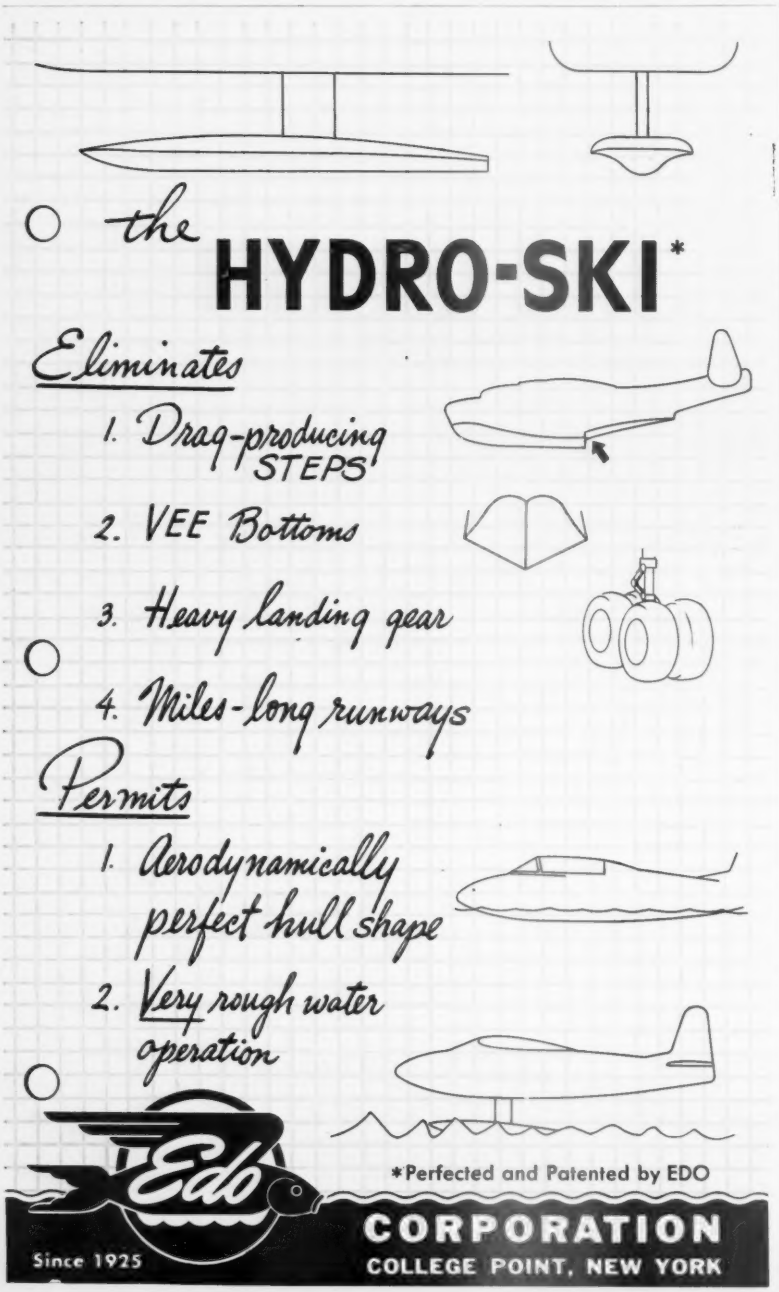
**The Shadowgraph of a Flat Flame.** F. J. Weinberg. *Proc. Royal Soc. (London), Ser. A*, June 12, 1956, pp. 510–517. Description of the structure of the shadow and calculation, for a shadow close to the flame, of the temperatures in the flame giving rise to the maximum and minimum light intensities. Includes quantitative correlation of the shadowgraph distribution with flame structure in a geometrically simple system for a shadow distant from the flame. Analysis considers the case of a beam of rays, initially parallel to each other, traversing a flat flame of finite diameter in premixed gaseous reactants, the one perpendicular to the flame being at right angles to the initial direction of the rays.

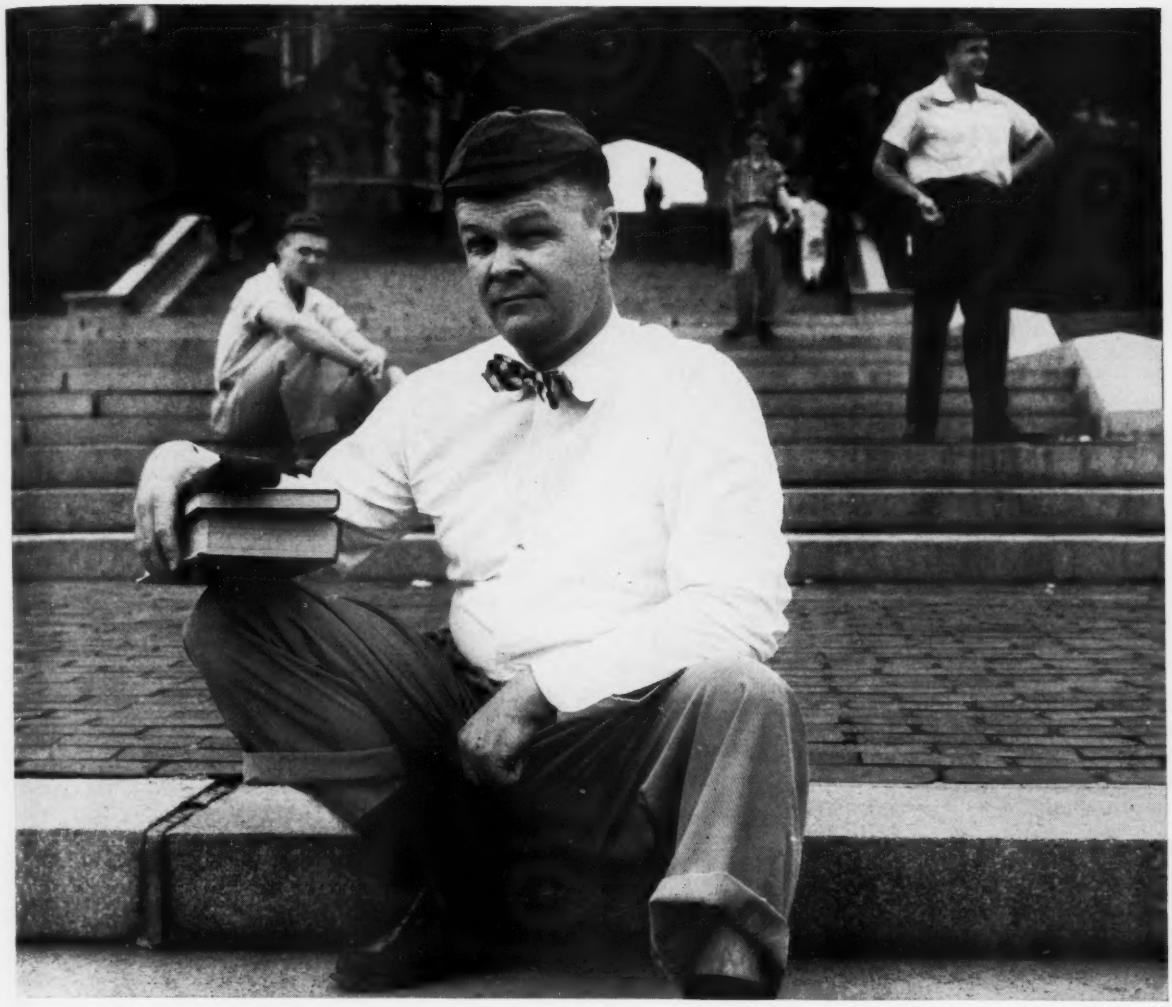
**Combustion in Turbulent Flow.** (Summary of Remarks at a Special Panel Meeting, Apr. 14–15, 1955, Johns Hopkins U., Appl. Phys. Lab.) *Jet Propulsion*, June, 1956, pp. 480–495. 43 refs. Flame Turbulence Measurements by the Method of Helium Diffusion, Arthur A. Westenberg. Schlieren and Direct Photographic Studies of the Turbulent Flame Structure, Joseph Grumer. Radiation from Turbulent Flames, A. L. Berlad. Combustion in Turbulent Flow, K. Wohl. Incipient Flame Propagation in a Turbulent Stream, H. L. Olsen and E. L. Gayhart. The Influence of Turbulence on Flame Propagation Rates, Ray E. Bolz and Henry Burlage, Jr. A Comment on Turbulent Combustion, Leslie S. G. Kovasznay. On the Flow Patterns of Flame, S. I. Pai. Turbulent Flames in Gases, Martin Summerfield. Remarks on Turbulent Flames, Béla Karlovitz. Flames in Turbulent Streams, W. G. Berl, J. L. Rice, and P. Rosen. Flame Spreading from Baffles, M. A. Weiss. An Investigation of the Burning Rates of Confined Turbulent Flame Jets, J. J. Zelinski, W. T. Baker, L. J. Matthews III, and E. C. Bagnall. Interactions of Flames and Flow Disturbances, G. H. Markstein. A Model for the Flame Front in a Viscous Heat Conductive Gas Mixture for Hydrodynamic Investigations, Boa-Teh Chu. Comments on Landau Instability, Boa-Teh Chu. One-Dimensional Laminar Flame Front Structure, Raymond Friedman. The Applicability of One-Dimensional Models to Three-Dimensional Laminar Bunsen Flame Fronts, Robert M. Fristrom.

**Second Quarterly Technical Status Report on Non-Stationary Combustion Studies (Covering Period From December 16th, 1955 to March 20th, 1956).** D. Bitondo, C. Hedges, E. Knuth, and N. Thomas. *ADC Rep. 2110-R2*, Mar. 28, 1956. 8 pp.

**Quelques Résultats d'Études de l'Allumage et de l'Inflammation des Propergols Liquides.** M. Barrère and A. Moutet. *La Recherche Aéronautique*, Nov.-Dec., 1955, pp. 27–34. 15 refs. In French. Results of studies of the ignition and burning of liquid propergols, using high-speed cinematography for the initial process in a combustion chamber with transparent walls. Optical density variations are found to follow the temperature changes. The study covers the effects of chemical and physical properties of the propellants in relation to the overall time lag in burning, ignition delay, accumulation of propellant in the combustion chamber, and the establishment of a stable regime, considered in relation to one another.

**Étude Expérimentale de la Combustion de Gouttes de Monergol.** Marcel Barrère and Hélène Moutet. *La Recherche Aéronautique*, Mar.-Apr., 1956, pp. 31–38. In French. Experimental study of the combustion of monergol droplets, with calculation of the diameter evolution.

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### *Heat Transfer*

**Theoretical and Experimental Investigation of Heat Transfer by Laminar Natural Convection Between Parallel Plates.** A. F. Lietzke. *U.S., NACA Rep. 1223*, 1955. 7 pp. Supt. of Doc., Wash. $0.15. Theoretical results presented in the form of equations for the velocity and temperature profiles and the ratio of actual temperature across the fluid to the temperature drop for pure conduction. Experimental results are compared to those theoretically obtained on the basis of the ratio of actual temperature drop to the temperature drop for pure conduction. Investigation involves parallel walls, simulated by using an annulus with an inner-to-outer diameter ratio near 1 for experimental work, which are oriented in the direction of the body force, with one wall heated and the other cooled uniformly.

**Theoretical Considerations of Combined Thermal and Mass Transfer from a Vertical Flat Plate.** E. V. Somers. *J. Appl. Mech.*, June, 1956, pp. 295–301. Analysis of evaporation and condensation phenomena associated with free-convective thermal and mass transfer from a wetted isothermal vertical flat plate to a gas at an ambient temperature and mass concentration which differ from those of the plate.

**Étude Expérimentale de la Convection Forcée de la Chaleur à Partir de Cylindres à Surface Rugueuse.** Edmond A. Brun, Giovanni Brunello, and Magdeleine Vernotte. *France, Min. de l'Air NT 60*, 1956. 33 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, 550 Fr. In French. Experimental study of the forced heat convection on the external surface of circular cylinders.

**The Effect on the Local Heat-Transfer Coefficient in a Pipe of an Abrupt Disturbance of the Fluid Flow: Abrupt Convergence and Divergence of Diameter Ratio 2/1.** A. J. Ede, C. I. Hislop, and R. Morris. *Chartered Mech. Engr.*, June, 1956, pp. 312–313. Abridged.

**A Rapid Analytical Method for Calculating the Early Transient Temperature in a Composite Slab.** W. F. Campbell. *Canada, NRC Div. Mech. Eng. Rep. MT-32*, Apr., 1956. 74 pp. 19 refs. Description of a method, based on the analogy between the one-dimensional flow of heat through a slab and the flow of an electric current along a transmission line, which is capable of handling many different boundary conditions.

## Vertical Take-Off Aircraft

**VTOL Fixed-Wing Aircraft.** Ken S. Coward. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 642.* 11 pp. 10 refs. Members, $0.35; nonmembers, $0.75. Results of Army-Navy-sponsored research, with details of design, operation, feasibility, and applications.

**VTOL-STOL Aircraft. II. I—A Comparison Between Pay-Load Capabilities of VTOL and Conventional Aircraft.** W. Z. Stepniewski. **II—Propeller-Lifted Tilt-Wing VTOL Aircraft.** Joseph Stuart, 3rd. **III—An Application of the Ducted Propeller to a VTOL Transport Airplane.**

James A. O'Malley, Jr. *Aero. Eng. Rev.*, Aug., 1956, pp. 44–55. 15 refs.

**STOL-VTOL Aircraft in the Air Mobile Army.** Michael J. Strok. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 646.* 8 pp. Members, $0.35; nonmembers, $0.75. Discussion of STOL-VTOL aircraft as part of the Army mission in national defense. Includes definition of an army air vehicle, required aircraft landing capabilities, specific missions of STOL-VTOL, limitations of helicopters, maintenance requirements, and suggested research and development areas.

**Lift on a Wing in a Propeller Slipstream as Related to Low Speed Flight.** Scott Rethorst. *IAS Natl. Summer Meeting, Los Angeles, June 18–21, 1956, Preprint 643.* 11 pp. Members, $0.35; nonmembers, $0.75. Outline of a theory for the characteristics of a wing extending through a propeller slipstream, which is based on lifting surface considerations and uses a method of analysis which is valid at all jet velocity ratios.

## Water-Borne Aircraft

**A Theoretical and Experimental Investigation of the Lift and Drag Characteristics of Hydrofoils at Subcritical and Supercritical Speeds.** Kenneth L. Wadlin, Charles L. Shuford, Jr., and John R. McGehee. *U.S., NACA Rep. 1232*, 1955. 22 pp. 16 refs. Supt. of Doc., Wash. $0.25.

**Investigation of High Length/Beam Ratio Seaplane Hulls with High Beam Loadings; Hydrodynamic Stability. XIX—The Interaction of the Effects of Forebody Warp, Afterbody Length and Afterbody Angle on Longitudinal Stability Characteristics.** J. K. Friswell. *Gt. Brit., MAEE Rep. F/Res/255*, Sept., 1955. 45 pp. 18 refs.

**Investigation of High Length/Beam Ratio Seaplane Hulls with High Beam Loadings; Hydrodynamic Stability. XXII—Tabulated Test Data.** D. M. Ridland, J. K. Friswell, and A. G. Kurn. *Gt. Brit., MAEE Rep. F/Res/262*, Sept., 1955. 106 pp.

**Methods for Reducing Seaplane Take-Off Distances to Standard Conditions.** J. A. Hamilton. *Gt. Brit., ARC CP 219* (Apr., 1954), 1955. 45 pp. BIS, New York. $0.81. Development of methods for the reduction of seaplane take-off distances to standard conditions of weight, wind, and ambient temperature. The derived expressions are applicable to the water-borne run and to the air-borne run up to 50 ft. height point, and the methods are applicable to take-off with simulated engine failure.

## Wind Tunnels & Research Facilities

**Effect of Wind-Tunnel Contraction on Free-Stream Turbulence.** Mahinder S. Uberoi. (*IAS 22nd Annual Meeting, New York, Jan. 25–29, 1954, Paper.*) *J. Aero. Sci.*, Aug., 1956, pp. 754–764. 18 refs. Investigation of turbulence in a wind tunnel which shows through the measurement of turbulent velocity that the longitudinal component decreases and the lateral component increases as the flow accelerates through the contraction.

**Tests of Humidity Effects on Flow in a Wind Tunnel at Mach Numbers Between 2.48 and 4.** Appendix I—**Simplified Treatment of the Condensation Shock.** R. J. Monaghan. *Gt. Brit., ARC CP 247* (Jan., 1955), 1956. 33 pp. BIS, New York. $0.90. Measurements of static and pitot pressure distribution in the working section of a 5- by 5-in. wind tunnel over ranges of absolute humidity at the inlet from $5 \times 10^{-5}$ to $3 \times 10^{-3}$.

**The "Tube" Wind-Tunnel.** H. Ludwieg. (*ZFW, No. 3, 1955, pp. 205–216.*) *Gt. Brit., MOS TIB/T4599*, Mar., 1956. 16 pp. Translation. Discussion of methods of meeting the requirements in wind tunnels at higher Reynolds and Mach Numbers, with emphasis on less expensive methods using such equipment as shock tubes and pressure-accumulator tubes.

**Low Speed Wind Tunnel Calibration of a Mk. 9A Pitot-Static Head.** J. E. Nethaway. *Gt. Brit., ARC CP 244* (Mar., 1955), 1956. 8 pp. BIS, New York. $0.27. Results of tests show the variation of pitot and static pressure error coefficients with incidence, at constant tunnel speed.

**Theory, Design, and Performance of a 420 kw Electrical Heater for Automatic Control of Stagnation Temperature in a Blow-Down Wind Tunnel.** William H. Hartwig. *U. Tex. DRL Rep. 383 (AFOSR TN 56-163)*, June, 1956. 89 pp. 14 refs. Development of an automatic feedback control heater using ignition tubes to control current in a 3-phase, 440-volt circuit for use in a supersonic wind tunnel.

**Airflows Studied in Miniature Smoke-Jet Wind Tunnels.** *Aero. Dig.*, June, 1956, pp. 35–39. Derivation of fundamental aerodynamic data from Lippisch wind tunnels and high-speed cameras photographing the time sequence of airflow events.

**Flutter Models and Aircraft Design.** J. C. A. Baldock. *Handley Page Bul.*, Summer, 1956, pp. 14–17. Design and construction of models having the same aeroelastic properties as the aircraft with completely different and simplified structure and giving the effects of stiffness or mass distribution changes quickly and accurately.


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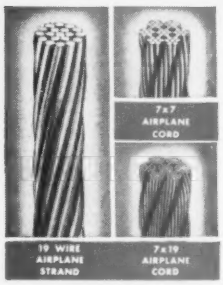


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## AERODYNAMICS

**Introduction à l'Etude de la Couche Limite (Introduction to Boundary Layer Theory).** Edmond Brun. Paris, Gauthier-Villars, 1955. 189 pp., figs. Fr. 1845, $5.28.

This general survey is concerned with boundary layer as the basis of such transport phenomena as fluid friction, convection, and diffusion. It forms a modification of part of the author's doctorate thesis work and his investigations at the Centre d'Etudes Supérieures de Mécanique, Sorbonne; it is also the first part of his course in aerothermics at the Ecole Nationale Supérieure d'Aéronautique, Paris.

Contents: Chapter (1) Review of Fundamentals; Definitions and General Theorems: (1a) Dynamic Phenomena; (1b) Thermal Phenomena. Chapter (2) Boundary Layer in a Fluid with Constant Physical Properties; The Flat Plate in Flow Parallel to its Surface: (2a) Dynamic Phenomena; (2b) Thermal Phenomena. Chapter (3) Boundary Layer in a Fluid with Constant Physical Properties: Two- or Three-Dimensional Flow: (3a) Dynamic Phenomena; (3b) Thermal Phenomena. Chapter (4) Diffusion Boundary Layer.

**Hydrodynamics.** Hugh L. Dryden, Francis D. Murnaghan, and H. Bateman. (National Research Council, Bulletin 84, 1932.) New York, Reprinted by Dover Publications, Inc., 1956. 234 pp., figs. $2.50.

## COMPUTERS

**National Simulation Conference Proceedings, Dallas, Tex., January 19–21, 1956.** Sponsored by Institute of Radio Engineers, Association for Computing Machinery, American Institute of Electrical Engineers, and Southern Methodist University Department of Electrical Engineering. Dallas, Tex., Southern Methodist University, 1956. 208 pp., illus., diagrs. $5.00.

Contents: Simulation of Military Vehicle Suspension Systems, I. J. Sattinger and E. B. Therkelsen. Analog Computer Computation of Propellant Linear Burning Rate, Arthur I. Rubin. Electric Analogy to Transient Heat Conduction in a Medium with Variable Thermal Properties, David R. Otis. Application of GEDA Analog Computers to Study Temperature Transients in a Plastic Windshield, P. J. Hermann. Performance Requirements for Flight Tables, H. Elmore Blanton. The Use of the Bendix Flight Table, E. J. McGlinn. The Design of a High Performance Hydraulic Servo, M. S. Feder and K. V. Bailey. Flight Simulator for Acoustic Homing Torpedoes, C. G. Beatty. Laboratory Evaluation of Systems Incorporating Scanning Reticles, H. H. Kantner and S. H. Cameron. Optical Simulation of Radar, William Blitzstein and Theodore Levine. High Accuracy Operational Digital Simulation, Julius Tou. Dynamic Tester Tape Preparation on ORDVAC, Glenn A. Beck. A Comparative Evaluation of Several Methods for Achieving Greater Angular Accuracy in Search Radars Using Simulation Techniques, Charlton M. Walter. The Derivation of Simulators of Gas Turbine and Other Physical Systems from Experimental Data, L. Wolin. The Uses of Post-Flight Simulation in Missile Flight Analysis, Richard G. Davis. Substitution Methods for the Verification of Analog Computer Solutions, Hans F. Meissinger. Analog Computer Prepatch Logic Using Sub-Routines, W. J. Wachter. An Approach to Digital Simulation, Max Palevsky. The Simulation of a Digital Differential Analyzer on the IBM 701, B. M. Tostanoski, C. J. Hoppel, and M. M. Dickinson. The Simulation of a Proposed Airborne Digital Computer on the IBM 701, J. R. Belford and M. E. Maron. A Simulator for Analysis of Sampled Data Control Systems. P. K. Giloth. General Evaluation of a Linear Time-Variant System, John M. Gallagher, Jr. Design of a Non-Linear Control System with Random Disturbances, Kenneth B. Tuttle. Time Domain Network Synthesis for an Analog Computer Setup, Joseph Otterman. Simulation of Dead Time, Norman L. Irvine. A Simulation System for the Study of Human Dynamics, John M. Stroud. The Applied Systems Development and Evaluation Center at the Navy Electronics Laboratory, Richard Coburn. An Analog Computer for Radioactive Fallout Prediction, H. K. Skramstad and J. H. Wright. An Exponential-Process Analyzer and Synthesizer, J. Ross Macdonald. The Gated Amplifier Computer Technique, Sidney Godet. A Wide-Band Direct-Coupled Operational Amplifier, C. Scott Deering. An Improved Diode Function Generator for Analog Computers, Robert A. Bruns. Use of Semi-Conducting Surfaces in Analog Function Generation, Vernon L. Larrowe and Margaret M. Spencer. Repeatable Generation of Noise with a Masked Cathode Ray Tube, L. B. Wadel, C. C. Calvin, and J. W. Atkins. A Comparison of Diode Switching Methods for Analog Function Generators, Otis L. Updike and John H. McLeod, Jr.

## ELECTRONICS

**NEL Reliability Bibliography.** Compiled by W. E. Jorgensen, I. G. Carlson, and C. G. Gros. San Diego, U.S. Navy Electronics Laboratory, May 1956. 101 pp.

The U.S. Navy Electronics Laboratory has issued this bibliography as part of the program to ensure that reliability is given more consideration in the design and production of electronic equipment. The material consists of publications issued since 1950, and these are listed under the following subject headings: (1) Circuit Design, (2) Components, (3) Electron Tubes, (4) Failure Analysis, (5) General, (6) Human Engineering, (7) Maintenance, (8) Mechanical Design, (9) Systems, (10) Testing. Entries in the bibliography are by title and contain the author, source of the reference, and the date. Each of the 404 references contains a brief abstract of about 100 words. The items are printed four to a sheet within ruled lines so that they may be cut out to form individual references, each on a 3- by 5-in. card size. Thus the bibliography may be kept on sheets and filed under subject groupings in a looseleaf notebook or cut into card size to provide a flexible card catalog with appropriate cross references by author, source, title, or subject.

**Handbook: Preferred Circuits, Navy Aeronautical Electronic Equipment.** Prepared by National Bureau of Standards for Bureau of Aeronautics, Department of the Navy. (NAVAER 16-1-519). Washington, U.S. Government Printing Office, September 1, 1955. 184 pp., diagrs. $1.75.

The purpose of the Preferred Circuits Manual is to encourage better engineering practice in the design of circuits for military electronic equipment. Preliminary studies sponsored by the Bureau of Aeronautics indicate that a high percentage of circuit functions are subject to standardization while still retaining the desired flexibility of equipment performance. The manual may be considered as a compilation of good design practice, not toward the limiting of effort in circuit design but as a standard against which true progress in circuit design may be measured. Although there is no current plan for issuing a military specification covering its use, the employment of the Preferred Circuits Manual is recommended as a guide in designing Navy aeronautical equipment. To achieve flexibility, the manual is arranged by preferred circuit numbers. The circuit is given first with its characteristics and other information enabling the engineer to select and construct the circuit. Successive pages carry a discussion, giving more information on use and design methods. For the designer whose interest extends beyond an immediate design problem, the steps which led to each preferred circuit are summarized in Part 2, "Notes to the Preferred Circuits Manual." The several steps covered with varying emphasis are (1) examples taken from an experimental survey, (2) a brief discussion of major differences and similarities in the several examples, (3) a summary of ranges of performance required, and (4) a presentation of design considerations too extensive to be included in the "Preferred Circuits Manual."

**Proceedings of the Second Conference on Radio Interference Reduction, Chicago, March 6–7, 1956.** Sponsored by Armour Research Foundation of Illinois Institute of Technology. Chicago, Armour Research Foundation, 1956. 368 pp., illus, diagrs., tables. $6.00.

Contents: Keeping Pace with Weapons Development, J. W. Klotz. Interference Suppression for Air Force Ground Electronic-Communications Equipment, J. Berliner and R. Powers. Interference Suppression for Air Force Airborne Electronic Communications Equipment, N. D. Flinn. Administration of the Army Radio Interference Program, E. V. Kavanaugh. The Bureau of Aeronautics Radio Interference Control Program, R. A. Schaller. Administration of the Bureau of Ships Interference Reduction

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**Proceedings of the Conference on Radio Interference Reduction;** Held at Armour Research Foundation of Illinois Institute of Technology, Chicago, December 7-8, 1954. Sponsored by Signal Corps Engineering Laboratories, Wright Air Development Center, and Navy Bureau of Aeronautics. Chicago, Armour Research Foundation, 1954. 352 pp., illus., diagrs.

Contents: Tri-Service Interference Survey, A. L. Albin.

Practical Suppression Techniques: Vehicular Radio Noise Suppression, B. H. Short. Control of Radio Influence Voltage in DC Rotating Electrical Machines, D. P. Motter. Shipboard Electronic and Electrical Installation Methods for Reduction of Electronic Interference, D. J. Jobe.

Measurements I: Problems of Radio Interference Measurements, W. Jarva. Instrumentation for Interference and Field Strength Measurement, J. F. Chappell. Research Investigations of Interference Measuring Instruments, R. M. Showers and A. Eckersley.

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Measurements II: A Method of Making Screen Room Interference Measurements, K. E. Mortenson and C. J. Truax. Broadband Absorbent Material for Use in Microwave Darkrooms, R. W. Wright and W. H. Emerson. Counter Techniques in Interference Measurements, M. M. Newman and J. R. Stahmann. Impulse Spectrum Analysis for Calibration of Impulse Noise Generators, S. Sabaroff.

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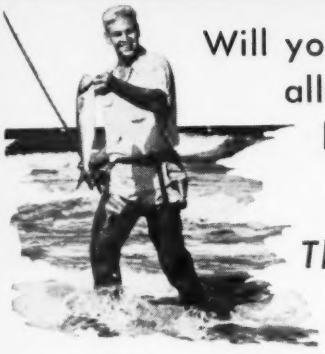

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Components: Low-Impedance Gaskets for Radio-Frequency Applications, V. Pulsifer and A. J. Hoehn. Suppression Capacitors, S. L. Shive. High-Performance Antenna Wave Filters for Radio Interference Suppression, M. K. Goldstein. Propagation and Antenna Considerations in the Prediction of Man-Made Interference, C. Polk.

**Precision Electrical Measurements;** An International Symposium, National Physical Laboratory, Teddington, Middlesex, November 17–20, 1954. New York, Philosophical Library, 1956. 322 pp., illus., diagrs. $12.

Contents: (1) Precision Measurements of Dielectric Constant, L. Hartshorn. (2) The Measurement of the Permittivity and Power Factor of Ordinary Solid and Liquid Dielectrics, E. Rushton and J. V. L. Parry. (3) Measurement of Dielectric and Magnetic Properties of Solids at Microwave Frequencies, M. Gevers. (4) A Precision Dual Admittance Bridge for the Range 3 Mc/s to 300 Mc/s, D. Woods. (5) A Bridge for the Measurement of the Admittance of Electrical Insulation at Very Low Frequencies, G. Mole and D. C. G. Smith. (6) Standard Methods for the Determination of Magnetization Curves, and Their Limitations, C. E. Webb. (7) Inductance Standards and the Calibration of Search Coils, G. H. Rayner. (8) Nuclear Magnetic Resonance and the Measurement of Magnetic Fields, R. L. Driscoll. (9) A Battery-Operated Magnetometer, T. M. Palmer. (10) A Radio-Frequency Permeameter, P. H. Haas. (11) Bridge Methods for Measurement of Magnetic Materials at Communication Frequencies, A. C. Lynch. (12) The Stabilization of A.C. Power Supplies Derived from Rotating Machinery, E. V. Hamon. (13) Primary Standard Wattmeters, O. Brune and J. W. Whittaker. (14) Alloys for Precision Resistors, C. Paterson. (15) Electrothermic Instruments for the Measurement of Alternating Current and Voltage, F. L. Hermach. (16) Measurement of Power at Audio-Frequencies, with Special Reference to the Equipment at the National Physical Laboratory for Calibrating Wattmeters, A. H. M. Arnold. (17) Measurements of Alternating and Direct Voltages with Special Reference to Absolute Methods, G. W. Bowdler. (18) Measurement of Impulse Voltages and Currents, P. R. Howard. (19) Compressed Gas Capacitors as Loss-Free Standards for High-Tension Measurements, A. Keller. (20) High-Voltage Measurement by Sphere-Gaps, F. S. Edwards. (21) A General Survey of Testing Techniques with High Impulse Voltages, W. G. Standring. (22) The Technique and Requirement of Impulse Generator Circuits, N. Hylten-Cavallius. (23) Impulse Testing of Transformers with Special Reference to Failure Detection, G. H. Hickling. (24) Transformer Impulse Tests with Special Reference to Fault Detection Requiring the Interpretation of Small Irregularities in Oscillograms, J. Neuve-Eglise. (25) Testing of Transformers with Special Reference to the Assessment of the Results of Such Tests, P. G. Provoost. (26) The Measurement of the Impulse Breakdown Strength of High-Voltage Cables, B. Salvage.

**Modern Oscilloscopes and Their Uses.** Jacob H. Ruiter, Jr. Rev. Ed. New York, Rinehart & Company, Inc., 1955. 346 pp., illus., diagrs., tables. $6.50.

This revised edition of a work which first appeared in 1949 will give the student, technician, and researcher the latest information on oscilloscopes. In addition to material on the application of the oscilloscope in shop, laboratory, and classroom, a chapter on the photography of patterns on the cathode-ray tube, a description of auxiliary equipment, and information on the manifold uses of the oscilloscope, there is a new chapter on Quantitative Measurements. The author is Manager, Advertising and Promotion, Allen B. DuMont Laboratories, Inc.

**The Changing Universe.** John Pfeiffer. New York, Random House, 1956. 243 pp., illus. $4.75.

Cosmic exploration through the use of enormous radio telescopes has opened up vast areas of the universe to systematic continuous examination. Celestial formations not discernible with optical instruments have been detected, and many new facts relating to familiar objects have been harvested by these new devices through their capture of radio waves emitted from regions in extraterrestrial space. Mr. Pfeiffer introduces the reader to the founders of the new science of radio astronomy and describes current and proposed research by leading astronomical and electronic engineering groups throughout the world.

Contents: (1) Broadcasts from Space. (2) Exploring the Radio Sky. (3) Tuning in on the Stars. (4) Listening to the Solar System. (5) The Sun in Action. (6) Among the Constellations. (7) Beyond the Milky Way. (8) Mapping New Skies. (9) Mysterious Signals. (10) Raw Material of the Universe. (11) Exploring Our Galaxy. (12) Inside the Spiral Arms. (13) Radar Astronomy. (14) The Future.

## MANPOWER

**Engineering and Scientific Manpower in the United States, Western Europe, and Soviet Russia.** Harris Collingwood. (U.S. 84th Congress, 2nd Session.) Printed for the use of the Joint Committee on Atomic Energy. Washington, U.S. Government Printing Office, 1956. 86 pp., diagrs., tables. $0.25.

It was the suggestion of Mr. Melvin Price, Chairman, Subcommittee on Research and Development, that the Government, business corporations, and universities should initiate a "crash program" to increase swiftly and steadily the number of adequately trained American scientists and engineers. At his request, Mr. Harris Collingwood, of the Library of Congress staff, undertook this study which is based on authentic documents and reports. It contrasts the results of the enormous effort by the Russians in the training of engineers and scientists with the effects of our own effort in this area. In terms of the three great political areas mentioned in the title of the report, the problem is considered in terms of the present availability of scientists and engineers and the backlog of trained individuals now active in the economy of the various countries, the numbers being graduated from the universities and colleges, the characteristics of the educational preparation in the several countries, and the extent to which high schools and other secondary schools are preparing young people for university and college work basic to engineering and scientific careers.

**The Growing Shortage of Scientists and Engineers;** Proceedings of the Sixth Thomas Alva Edison Foundation Institute, November 21–22, 1955. New York, New York University Press, 1956. 132 pp. $4.00.

Contents: The Manpower Situation in Engineering and Science, Henry H. Armsby. Freedom's Need for the Trained Man, Lewis L. Strauss. Manpower Policy and the Efficiency of Utilization of Scientists and Engineers (Panel Discussion). The Problem: Its Dimensions and What Is Being Done (Panel Discussion). An Inventor Looks at Education, Charles F. Kettering. Encouraging Scientific Talent (Panel Discussion). Engineering and Scientific Education, Hyman G. Rickover. The Improvement of the Quality of Science Teaching (Panel Discussion). What are the Failures of Science Education in America (Panel Discussion).

## MATERIALS

**Résistance des Matériaux, Théorique et Expérimentale; Tome 1, Théorie de l'Elasticité et des Structures Elastique (Resistance of Materials, Theoretical and Experimental; Vol. 1, Theory of Elasticity and Elastic Structures).** Robert L'Hermite. Paris, Dunod, 1954. 860 pp., figs. Fr. 8,400. In French.

The present work, which is based on a survey of the literature, is the first of a series of four volumes offering a comprehensive survey of theory and methods of calculation in the resistance of materials. Volume 1 of the compendium is concerned with the theories of elasticity and elastic structures, Volume 2 is to be concerned with stability, yielding, and plasticity, Volume 3 with the mechanics of materials, and Volume 4 with dynamic phenomena, shock and vibration, combined materials, composite structures, statistics, and safety. According to plan, in each chapter the basic principles of the subject are treated first; then particular cases and various methods of treatment are analyzed, and practical results are presented in figures and tables. Reference features include annotated bibliographies (in addition to footnote references) and subject and author indexes. The author is Director of the French Laboratories of Building and Public Works.

Contents: (1) Theory of Elasticity. (2) Elasticity of Systems in Two Dimensions (Plane Elasticity). (3) Internal Equilibrium of Bodies (By Median Fibers): Tension and Flexure. (4) Internal Equilibrium of Bodies (By Median Fibers): Torsion. (5) Theory of Isostatic Structures: Statically Determinate Straight, Curved, or Jointed Parts. (6) Theory of Hyperstatic (Statically Indeterminate) Structures: Straight Beams and Beam Systems. (7) Theory of Hyperstatic (Statically Indeterminate) Structures: Curved Beams, Arches, and Portal Frames: Three-Dimensional Structures. (8) Flexed Plates and Slabs. (9) Shells. (10) Critique and Summary.

## MECHANICS

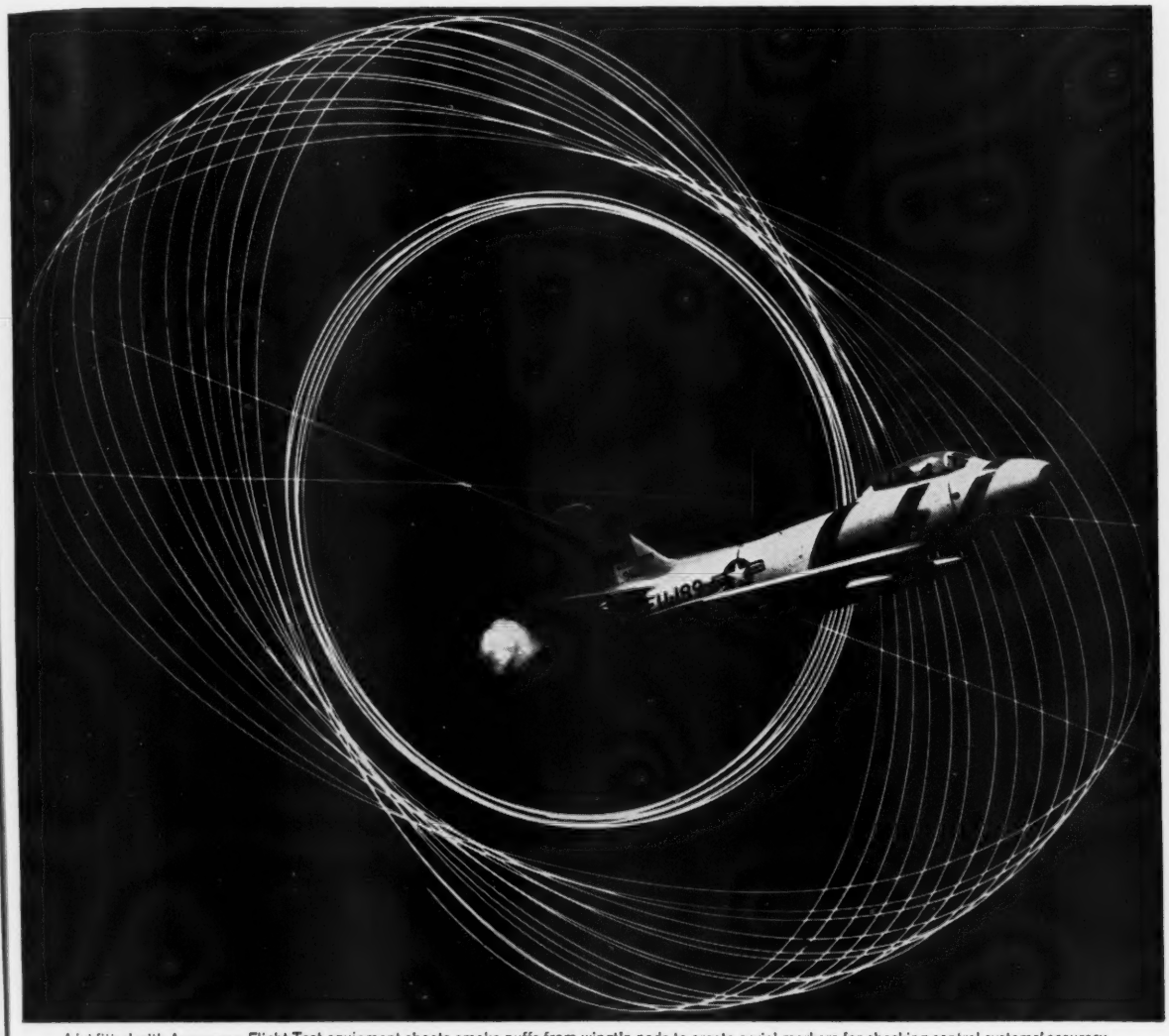
**The Principles of Mechanics, Presented in a New Form.** Heinrich Hertz. Preface by H. Von Helmholtz; Authorized English Translation by D. E. Jones and J. T. Walley; With a New Introduction by Robert S. Cohen. New York, Dover Publications, Inc., 1956. 271 pp. $1.75.

A reprint of the 1899 edition. Attempts to provide a rigorous formulation of the principles of mechanics, not in terms of energy or force as in previous systems, but in terms of space, time, and mass.

## MILITARY AVIATION

**Soviet Air Power; with Supplement.** Richard E. Stockwell. New York, Pageant Press, Inc., 1956. 238 pp., illus., maps. Supplementary Volume: 13 folding charts. $7.50 the set.

This work by the former editor of *Aviation Age* chronicles the growth of Russian air power from the early 1900's to the present. The opening chapters portray the accomplishments of such leading designers and engineers as Tupolev, Ilyushin, Lavochkin, Mikoyan, and Yakovlev as well as the production methods developed under successive Soviet Five-Year Plans. The performance of Russian aircraft against the Luftwaffe in World War II is recounted, and postwar technological advances in air-frame design and power plants are described in some detail. Credit for much of the progression in these fields is laid by the author to German scientists and technicians, but equal credit is given to the aircraft production methods of the Russians and to the emphasis they place on simplicity of preliminary design. The Soviet military structure, particularly the six separate air arms controlled by the Ministry of Defense, is examined by Mr. Stockwell, as are the air forces and civil air fleets maintained by the satellite nations of the West and by Communist China. Special attention is given to Russian guided-missile development. The supplement supplies detailed data on 70 aircraft and 55 turbojet, turboprop, and rocket engines currently in production or undergoing test. Included are maps of Russian aircraft production centers, long-range bomber bases, missile test



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centers and launching sites, and the principal air routes within the Soviet Union. The text includes a bibliography of books and periodicals surveyed for relevant material and closes with illustrations of the leading types of jet aircraft operational with the Soviet air forces.

**General View of Japanese Military Aircraft in the Pacific War.** Kazuo Baba, Chief Editor. Japanese text with separate English translation. Tokyo, Kantosha Company Ltd.; Hampton Bays, N.Y., Hampton Books, 1955. 2 Vols.; 324, 190 pp., illus., diagrs., folding charts. $6.35 the set.

The combat records and construction details of 100 Japanese Army, Navy, and experimental aircraft are listed in this volume, with supplementary notes relating to their operational performance, to engine and air-frame development, and to wartime production schedules in the home islands. Much of the text is devoted to a description of aerodynamic features, armament capacity, equipment, and continual remodification of front-line and home defense aircraft. Numerous photographs and three-view illustrations accompany the text. Included in the table of contents are the Japanese name, code name, type symbol, and the Allied code name for all the aircraft appearing in this book. The tactical considerations underlying the development of each type are discussed, particularly in the section on experimental aircraft, and much information is given on prototypes and power plants remaining uncompleted at the time of Japan's surrender to the Allied Powers.

## MISSILES

**Guided Missiles in War and Peace.** Nels A. Parson, Jr. Cambridge, Mass., Harvard University Press, 1956. 161 pp., illus., diagrs., biblio. $3.50.

Written by a professional Army officer, this volume is a critique of the impact of guided missiles upon military operations. The employment of the new weapon in aerial, naval, and land combat is discussed without regard for the present organizational structure of the Armed Forces of the United States and presents the author's personal conclusions with respect to the integration of guided missiles into combat units of the future.

Contents: (1) Your Acquaintance Is Inevitable. (2) Why Guided Missiles? (3) From Wan Hu to von Braun. (4) How They Fly. (5) Guided and Misguided. (6) Flying Cuspidors and Stovepipes. (7) Air Warfare with Guided Missiles. (8) Guided-Missile Navies. (9) Guided Missiles in Land Warfare. (10) Missiles of Peace. References.

## PHYSICS

**Astrophysical Quantities.** C. W. Allen. London, University of London, The Athlone Press; New York, John de Graff, Inc., 1955. 253 pp., tables. $10.

In this volume, the Perrin Professor of Astronomy at the University of London has assembled in tabular form the experimental and theoretical values, constants, and conversion factors that are fundamental to the science of astrophysics. The opening chapters are devoted to the enumeration of physical data including general mathematical and astronomical constants, units of measurements, atomic weights, numbers and functions, spectroscopic terminology, and line intensities and radiation emission. In view of the oncoming International Geophysical Year, much of the data concerning the Earth will be of particular interest. These include atmospheric standards, variation of meteorological quantities with latitude, distribution of earth atmosphere with height, atmospheric refraction and air path, and the absorption of gases. Additional tables quote values for atmospheric electricity and ozone density as well as night sky illumination factors and relevant ionospheric and geomagnetic constants. The chapters on the solar system furnish data on the structures, atmospheres, variations, and orbits of the earth, sun, planets, satellites, and comets.

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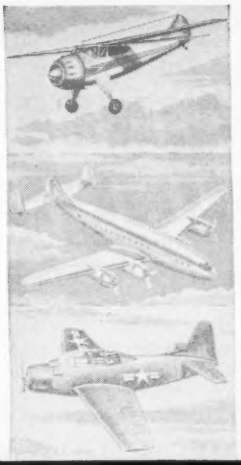

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Quantitative descriptions of the stars, star systems, interstellar material, and nebulae follow with some attention given to those bodies exhibiting special characteristics. Professor Allen has supplied numerous references in order that the reader may check any data as regards numerical value or meaning and closes his volume with incidental tables of interest to astronomers and astrophysicists.

**Solid State Physics; Advances in Research and Applications, Vol. I.** Edited by Frederick Seitz and David Turnbull. New York, Academic Press, Inc., 1955. 469 pp., diagrs. $10.

This is the first in a series that will encompass about a dozen volumes. The purpose is to publish most of the basic reviews on solid state science and to review comprehensively all of the important facets of the subject. Qualified scientists will prepare articles on parts of the field that are currently appropriate. The articles will be of three general types: (1) broad elementary surveys that have particular value in orienting the advanced graduate student or an investigator having little previous knowledge of the subject; (2) broad surveys of fields of advanced research that serve to inform and stimulate the more experienced investigators; (3) more specialized articles describing important new techniques, both experimental and theoretical. The volumes will be published semiannually for a period of time. After a few years it is expected that the volumes will be published annually.

Contents: Methods of the One-Electron Theory of Solids, John R. Reitz. Qualitative Analysis of the Cohesion in Metals, Eugene P. Wigner and Frederick Seitz. The Quantum Defect Method, Frank S. Ham. The Theory of Order-Disorder Transitions in Alloys, Toshinosuke Muto and Yutaka Takagi. Valence Semiconductors, Germanium and Silicon, H. Y. Fan. Electron Interaction in Metals, David Pines. Author Index. Subject Index.

**Solid State Physics; Advances in Research and Applications, Vol. 2.** Edited by Frederick Seitz and David Turnbull. New York, Academic Press, Inc., 1956. 468 pp., diagrs., tables. $10.

Contents: Nuclear Magnetic Resonance, G. E. Pake. Electron Paramagnetism and Nuclear Magnetic Resonance in Metals, W. D. Knight. Applications of Neutron Diffraction to Solid State Problems, C. G. Shull and E. O. Wollan. The Theory of Specific Heats and Lattice Vibrations, Jules de Launay. Displacement of Atoms during Irradiation, Frederick Seitz and J. S. Koehler. Author Index. Subject Index.

## POWER PLANTS

**Thermopropulsion des Avions; Turbines et Compresseurs Axiaux (Thermal Propulsion of Aircraft; Axial Turbines and Compressors).** René Bidard. 2nd Ed. Paris, Gauthier-Villars, 1954. 338 pp., illus., figs. Fr. 4,050, $11.57.

The subject matter of this book has been taught by the author in the Ecole Nationale Supérieure d'Aéronautique in Paris since 1946. In this second edition a complete calculation of the gas-turbine cycle is presented. There is also a study of the case where the turbine or the compressor can be considered as exchanging heat with the outside atmosphere—a case which is of greater importance with industrial turbines but which explains well the functioning of these turbomachines. New to this edition also are a study of the external aerodynamics of aircraft gas turbines and a study of the ramjet. To the chapter on cascades has been added material on blade form, estimation of characteristics, and the effect of Mach Number. The chapter on combustion has been enlarged by a treatment of combustion in high-speed flow, such as that in afterburners, and a discussion of heat exchangers has been included. The more than 1,300 literature references mentioned in the text are collected in a separate section.

## RESEARCH

**Proceedings of the Ninth Annual Conference on the Administration of Research;** Northwestern University Technological Institute, Evanston, Ill.,

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DEPARTMENT OF TECHNOLOGY BUFFALO AND ERIE COUNTY PUBLIC LIBRARY

September 7–9, 1955. New York, New York University Press, 1956. 107 pp. $4.00.

Contents: Research Relationships Between Government and the University, Ralph A. Morgen. Research Relationships Between Government and Industry, Daniel P. Barnard. Summary of Statistical Data on Government-Sponsored Research, Raymond H. Ewell. University Executives' Viewpoints on Government Research Relationships, J. W. Buchta. Industry Executives' Viewpoints on Government Research Relationships, Allen Abrams. Industry and University as Sources of Research Operations for the Armed Services, D. L. Putt. Industry, Universities, and National Laboratories as Sources of Research Operations for the Atomic Energy Commission, Thomas H. Johnson. How Can Methods of Obtaining and Awarding Contracts Be Improved, Morris T. Carpenter. How Can the Working Relations Between Contractors and Government Administrators Be Improved, John H. Richardson. Closing Remarks, R. W. Cairns. Negotiating and Procuring the Contract, William Davis. Effective Relations in Government-Sponsored Research, Thomas Killian. Utilizing Research Results, Charles Kimball. Communications in Research, Oscar Maier. Panel—The Future of Research: For Industry, E. D. Reeves; For Universities, Clifford C. Furnas; For Government, H. Guyford Stever.

**A Decade of Research, 1946–1956.** Buffalo, Cornell Aeronautical Laboratory, Inc., of Cornell University, 1956. 67 pp., illus.

The following aspects of the Laboratory are briefly summarized—history, technical and educational programs, public service, and business operations. The technical program is detailed under 19 separate areas of aeronautics. The contributions of the different departments are outlined, and a quick résumé is given of current research.

## ROTATING WING AIRCRAFT

**Report on the Helicopter;** The Helicopter and its Role as a Transport Vehicle. Samuel C. Williams. (Brundage Story and Rose Research Reports, Series A-1.) New York, Brundage Story and Rose; Hoboken, N.J., Distributed by Stevens Book Store, Stevens Institute of Technology, 1956. 220 pp., illus., tables. $2.50.

Mr. Williams, Associate Professor of Industrial Engineering, Stevens Institute of Technology, has undertaken a review of developments in the helicopter industry from 1939 to date. His survey attempts to measure the effect of the more important forces which will determine the industry's course and its growth prospects during the next decade. The areas discussed are (a) mobility in transportation, (b) past history and present size of the manufacturing industry, (c) present and potential applications for the helicopter, (d) capital and operating costs, (e) engineering problems confronting producers and users, and (f) the relative importance of future markets for this novel form of transportation. There are 17 illustrations and 56 statistical tables highlighting pertinent information. The introduction of the book contains a concise and comprehensive résumé of the scope, summary, conclusions, and recommendations.

**Principles of Helicopter Engineering.** Jacob Shapiro. New York, McGraw-Hill Book Company, Inc., 1955. 433 pp., illus., diagrs., tables. $12.50.

The science and art of rotating wing aircraft represent the work of a large number of engineers and scientists. This work has been synthesized, along with the results of many publications by Government, establishments, companies, and individuals, to form a definitive volume covering all aspects of the helicopter. Supplementary material includes a glossary, a notation list of physical quantities, and a bibliography. The author is a consulting designer and engineer and Managing Director, Servo-Tech Ltd., London.

Contents: Chapter (1) Rotating Wings in Steady Flight: The Actuator Disc, The Real Rotor, Rotor Performance, Aerodynamic Problems, Rotor Analysis. Chapter (2) Performance

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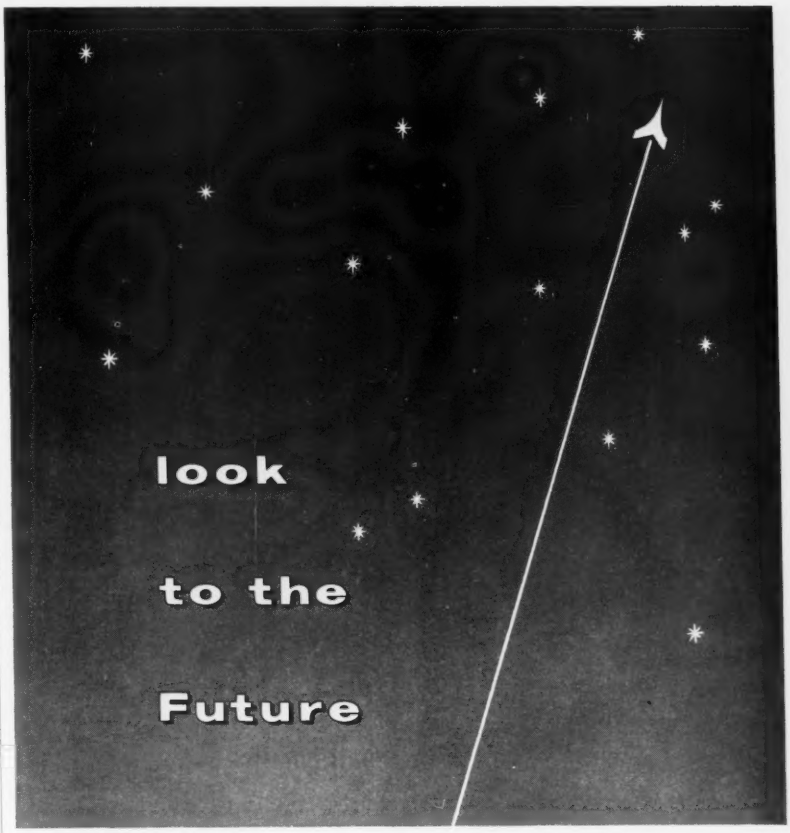


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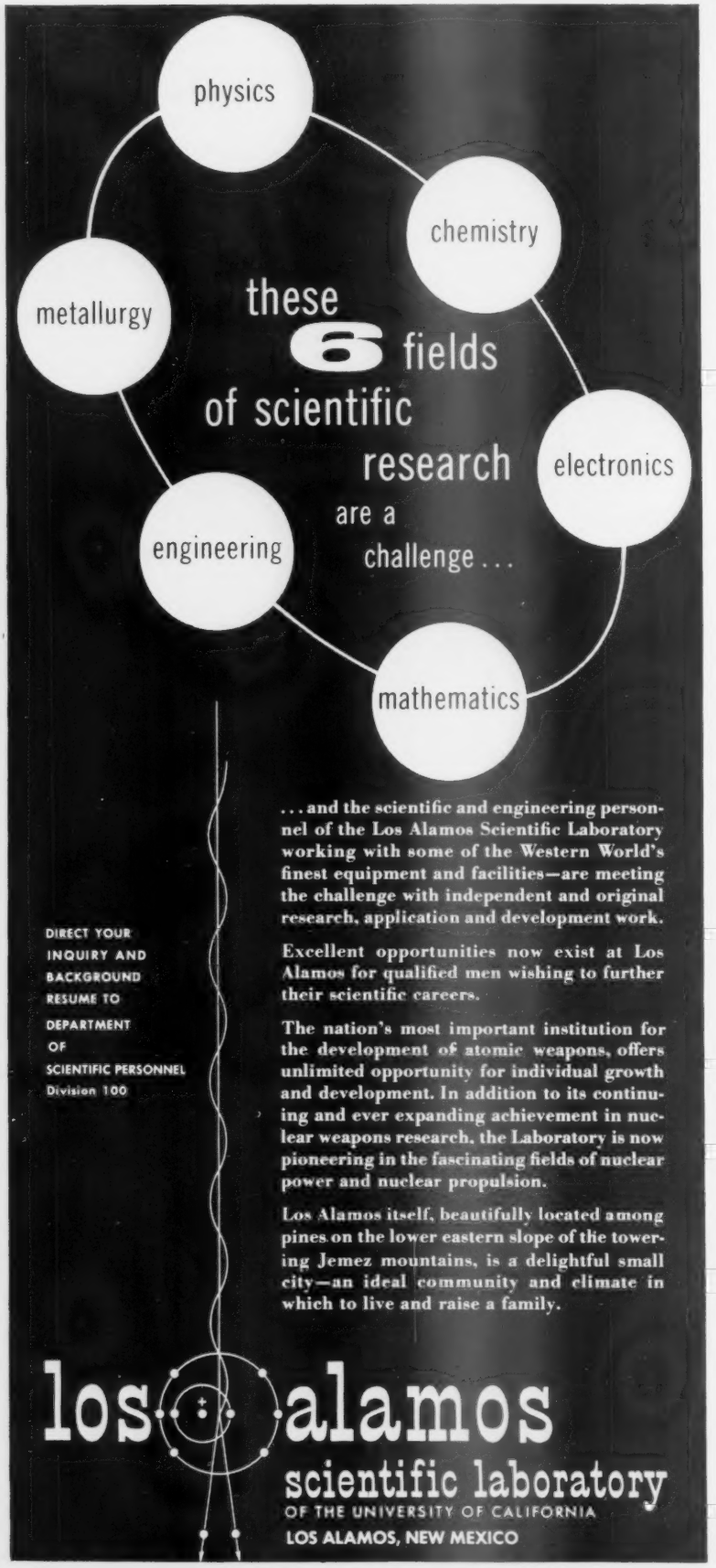
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**Théorie des Hélicopteres Monorotors (Theory of Single-Rotor Helicopters).** Jean-J. Ginoux. (Centre Belge de Navigation, Publication No. 14.) Brussels, Office de Publicité SA, 1954. 230 pp., illus., figs., tables.

This book was developed out of a series of lectures given by the author at the Institut d'Aéronautique of the Université Libre of Brussels. The first chapter is devoted to a general description of the helicopter. The first part, in which are compared the chief characteristics of airplanes and rotating wing aircraft, is for a reader who already has some ideas of the subject or who wishes to gain a general view of the whole topic after the first reading of the book. The second part is intended to explain the different types of helicopters and rotor heads before going into the special treatment of single-rotor machines with articulated blades. Photographs give some examples of actual construction, and there is some discussion based on detail drawings. The second chapter is concerned with hovering flight and ascending vertical flight: The theory of helicopter momentum is combined with that of the blade element, and expressions are obtained for the lifting force and the engine power. Blade proportions are studied in relation to rotor lift in hovering flight, and performance calculations are made for a given rotor. The third chapter treats descending vertical flight with and without power; the method of calculation used is semiempirical in the sense that it is based on flight-test results. Chapter (4) is concerned with pitch variation, flutter, and oscillations of the blade system and serves as an introduction to the next chapter. Chapter (5), a study of the single-rotor helicopter in translational flight, is divided into three parts: rotor theory, helicopter performance calculation, and optimum conditions in horizontal flight. Chapter (6) is an evaluation of the flight characteristics of single-rotor helicopters, taking into account helicopter control in its physical aspect and static and dynamic stability. At the end, there are summaries of the notation used in the book, a glossary of French and English helicopter terms, and four folding charts giving characteristics and performance of helicopters built or on the design boards at the time of writing.

**Report of Proceedings, Third Convertible Aircraft Congress;** Held at The Franklin Institute, Philadelphia, November 25, 1955. Marian Station, Pa., Distributed by E. Burke Wilford, 1956. 94 pp., illus., diagrs. $2.00.

This Third Congress was in the nature of a review of developments in the field since 1952 and a projection into the future. The bulk of the text consists of the following panel discussions: applied research methods, high-speed flight, power plant manufacturers, real safety, and air transport. Individual talks include: Review of Air Force Convertiplane Projects, William E. Zins. Philadelphia Pioneering in Aviation, Paul Thomas. Terminals for Tomorrow's Short-Haul Aircraft, John R. Wiley. Getting Ideas to the Government, William B. Bunker.

## SPACE TRAVEL

**Experiments in the Principles of Space Travel.** Franklyn M. Branley. New York, Thomas Y.

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Crowell Company, 1955. 119 pp., diagrs., tables. $2.00.

The purpose of this brief volume is two-fold in that it undertakes to explain the basic laws of science relating to rocketry and space travel and thereby to enable the reader not only to conduct simple experiments verifying these laws but also to separate fiction fom science in the literature devoted to extraterrestrial flight. Numerous illustrations carry forward the author's explanations of such matters as the measuring of distance in space, the design of rockets and their power plants, temperature and pressure control, sources of power, and the effects of gravity. The author's personal view is that space travel will be limited to the solar system owing to the short span of human life compared with the time required to traverse the enormous distances separating the planets from the nearest stars.

### STRUCTURES

**Freiszylinderschalen (Circular Cylindrical Shells);** A Tabular Compilation for Computing Circular Cylindrical Shell Structures of Arbitrary Dimensions. Dieter Rüdiger and Joachim Urban. Leipzig, B. G. Teubner, 1955. 270 pp., tables. DM 24. In English and German.

This book first gives an introduction into the theory of circular cylindrical shells, established by W. Flügge. The basic equations are simplified according to a proposition made by L. H. Donnell in 1933, by neglecting "Bernoulli's Hypothesis." The numerical evaluation of the solution of Donnell's differential equation is rendered possible by using a dimensionless parameter, first applied by H. Neuber, which connects the three independent dimensions of the circular cylindrical shell—length, radius, and thickness of shell. By defining suitably the four redundants, acting between each edge member along the generatrix and the circular cylindrical shell, it is possible to extend the tabulation of the integration-constants for unit load cases proposed by Dischinger so that the stress and displacement condition of the shell may be calculated for unit values of redundants at each point of the shell. The evaluation of the solution has been done for 48 parameter-values 0.03(0.01)-0.30(0.03)0.90.

### THERMODYNAMICS

**Proceedings of the Gas Dynamics Symposium on Aerothermochemistry, August 22–24, 1955.** Edited by Donald K. Fleming. Sponsored by Northwestern University and American Rocket Society with the Cooperation of the ARDC, USAF. Evanston, Ill., Northwestern University, 1956. 284 pp., illus., diagrs., tables. $4.00.

*Contents:* Combustion of Condensed Phases: From Liquid Stream to Vapor Trail, C. C. Miesse. Steady State Burning of a Liquid Droplet with Finite Reaction Kinetics, Jack Lorell, Henry Wise, and R. S. Carr. A Study of Radius and Surface Temperature Variations of an Evaporating Liquid Droplet in the Absence of Macroscopic Convection, S. L. Soo and H. K. Ihrig, Jr. A Theory of the Spread of Flame in a Propellant Bed, G. P. Wachtell.

Nonsteady Combustion: Combustion Instability, Luigi Crocco and J. Grey. Oscillatory Combustion in Rocket Propulsion Engines, A. O. Tischler and Theodore Male. Cellular Slot Burner Flames, G. H. Markstein and D. Schwartz. Vibration of the Gaseous Column Behind a Strong Detonation Wave, Boa-Teh Chu.

Laminar Flames: Theoretical Studies of Laminar Flame Propagation, S. S. Penner and T. H. Crowe. An Analysis of Flame Propagation Based on Simplified Reaction Kinetics, E. Mayer and H. Carus. Burning Velocities by the Bunsen Burner Method, J. M. Singer, Joseph Grumer, and E. B. Cook. Study of Pressure Dependence of Burning Velocity by the Spherical Vessel Method, John Manton and B. B. Milleken. Studies of the Ignition of Gaseous Hydrocarbons, C. F. Mozer and R. K. Sherburne.

Turbulent Combustion: Status of Research of the Physics of the Turbulent Combustion in Premixed Gases, Martin Summerfield. Mathematical Theory of Turbulent Flames, J. M. Richardson. An Investigation of the Burning Rates of Confined Turbulent Flames, J. J. Zelinski, W. T. Baker, L. J. Mathews, III, and E. C. Bagnall. Diffusion Flames, Itsuro Kimura and Seiichiro Kumagai.

Flame Stabilization: Experiments Concerning the Mechanism of Flame Blowoff from Bluff Bodies, Edward E. Zukoski and Frank E. Marble. Studies of Flow and Mixing in the Recirculation Zone of Baffle Type Flameholders, A. A. Westenberg, W. G. Berl, and J. L. Rice. Aerothermochemical Aspects of Flameholder Performance, John W. Bjerklie. Combustion Performance of Baffle Type Flameholders Located in Jet Engine Diffusers, Edward P. French.

Detonation and Thermodynamics: Considerations for the Attainment of a Standing Detonation Wave, J. Rutkowski and J. A. Nicholls. Review of Recent Work on Strong Shock Waves Done at Cornell University, R. M. Patrick and A. Kantrowitz. Total Entropy Production in Chemically Irreversible Processes, Shao-Lin Lee and John F. Lee. Some Thermodynamic Properties of $CH_2$ Air Combustion Gases, H. N. Powell and S. N. Suciu.

Banquet Address: Technical Military Superiority Is Still Needed, H. Guyford Stever.

**1956 Heat Transfer and Fluid Mechanics Institute;** Preprints of Papers. Held at Stanford University, Stanford, Calif., June 21–23, 1956. Stanford, Stanford University Press, 1956. 278 pp., illus., diagrs. $5.75.

Contents: (1) Ebullition from Solid Surfaces in the Absence of a Pre-Existing Gaseous Phase, S. G. Bankoff. (2) Effect of an Ultrasonic Field on Boiling Heat Transfer—Exploratory Investigation, S. E. Isakoff. (3) Solving the Melting Problem Using the Electric Analogy to Heat Conduction, David R. Otis. (4) Effect of Axial Fluid Conduction on Heat Transfer in the Entrance Regions of Parallel Plates and Tubes, P. J. Schneider. (5) Heat Transfer in a Pipe with Turbulent Flow and Arbitrary Wall-Temperature Distribution, C. A. Sleicher, Jr., and M. Tribus. (6) Heat Transfer of a Laminar Pipe Flow with Coolant Injection, S. W. Yuan and A. B. Finkelstein. (7) Heat Transfer by Forced Convection from a Horizontal Flat Plate into a Turbulent Boundary Layer, A. C. Spengos and J. E. Cermak. (8) On the Changing Size Spectrum of Particle Clouds Undergoing Evaporation, Combustion, or Acceleration, A. H. Shapiro and Alve J. Erickson. (9) Experimental Study of the Velocity and Temperature Distribution in a High Velocity Vortex Type Flow, J. P. Hartnett and E. R. G. Eckert. (10) Natural Convection Heat Transfer from a Horizontal Cylinder Rotating in Air, David Dropkin and Arieh Carmi. (11) An Analog Solution of the Navier-Stokes Equation for the Case of Flow Past a Flat Plate at Low Reynolds Numbers, E. Janssen. (12) On the Supersonic Flow of a Viscous Fluid over a Compression Corner, Raymond L. Chuan. (13) Heat Transfer to a Yawed Infinite Cylinder in Compressible Flow, Eli Reshotko. (14) The Unsteady Laminar Boundary Layer on a Flat Plate, Sin-I Cheng and David Elliott. (15) Thermodynamics of the First Order, Y. S. Touloukian and P. S. Lykoudis. (16) Non-Linear Problems in Thermodynamics of Irreversible Processes, I. Prigogine. (17) Thermoelasticity and Irreversible Thermodynamics, M. A. Biot.

### VIBRATION

**Mechanical Vibrations.** J. P. Den Hartog. 4th Ed. New York, McGraw-Hill Book Company, Inc., 1956. 436 pp., diagrs. $9.00.

Originally the outgrowth of a course of lectures given to students in the Design School of the Westinghouse Company in Pittsburgh, Pa., the first edition of this book was published in 1934. It is intended for the student engineer and the practicing engineer. While dealing with vibration phenomena in a thoroughly technical manner, the text emphasizes the many applications of principles and calculations to the vibration problems encountered by the practicing engineer. Complete explanations and proofs are given without mathematics higher than simple differentiations and integrations. The number of problems has been increased in this edition. New material has been added on von Kármán vortices and on nonlinear vibrations, with examples of cases that have appeared in practice since 1947.

### YEARBOOKS

**Aviation Facts and Figures, 1956.** Official Publication of the Aircraft Industries Association of America. Washington, Lincoln Press, Inc., 1956. 103 pp., diagrs., tables. $1.00.

The contents of this fourth edition represent a compilation of facts gleaned from many sources in the world of aviation during the past year. United States air power, military and civil, and the aircraft industry which designs and produces aircraft and missiles are analyzed both statistically and textually.

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**Engineers**—Opportunities in a new, long-range, stable effort in Air Defense problems are available for electrical and electronic engineers or scientists, physicists, applied mathematicians, and mechanical engineers. This effort involves high-level creative origination and improvement of components of Air Defense Systems considering immediate and future problems. Effort will be accomplished by small groups considering sequential problems. Direct experience is not a major consideration providing that the applicant's background forms a framework of adaptable or supporting skills. Salary range, $5,440 to $11,610. Interested individuals are invited to write for information or send résumé to Chief, Air Defense

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**Professors**—The Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, has vacancies in the Department of Mathematics. Most of the work is at an advanced undergraduate and graduate level. Employment will be effected in accordance with Civil Service regulations. Grade levels available are GS-9 ($5,400), instructor; GS-11 ($6,390), assistant professor; and GS-12 ($7,570), associate professor. Applications should be made on Standard Form 57 or by letter to Head, Department of Mathematics, Resident College, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

**Instructor—Aeronautical Engineering**—The University of Southern California has an opening for an instructor in its Aviation Safety Program. Students are U.S. Air Force, Navy, and Army pilots attending 8-week courses on temporary duty status. Instructors should have B.S.A.E. and preferably flying experience and acquaintance with rotary wing aircraft. This is a full-time position at a base salary of $8,500 for an 11-month year with usual academic holidays. It involves 15 hours of classroom instruction per week. Time may be made available for study or consultation service in industry. Position to be filled by October 15, 1956. Appointment will be made early in October. Send inquiries to Aviation Safety Division, U.S.C., Los Angeles 7.

**Engineers**—The Naval Ordnance Experimental Unit has openings for aeronautical, mechanical, and electronic engineers for technical management of guided-missile system development programs. These positions are in the GS-12, 13, and 14 levels with starting yearly salaries of $7,570, $8,990, and $10,320 and are located in Wash., D.C. Applications on Standard Form 57 should be sent to Officer in Charge, Naval Ordnance Experimental Unit, c/o National Bureau of Standards, Wash. 25, D.C.

**Engineers—Aeronautical, Mechanical, and Electronic**—The Technical Development Center of the Civil Aeronautics Administration at Indianapolis is seeking engineers to conduct development, applied research, experimentation, evaluation, and testing projects in connection with aircraft structures, power plants, instrumentation, electronic and other aids to air navigation, communication, and traffic control. Requirements are as follows: GS-5, B.S. degree or experience equivalent, $4,480; GS-7, B.S. degree or experience equivalent plus 6 months' experience, $5,335; GS-9, B.S. degree or experience equivalent plus 1½ years' experience, $6,115; GS-11, B.S. degree or experience equivalent plus 2½ years' experience, $7,035. Write or send application on Standard Form 57 to Personnel Officer, Civil Aeronautics Administration, Technical Development Center, P.O. Box 5767, Indianapolis.

**Aeronautical Design Engineers**—The Aircraft Engineering Division of Lear, Incorporated, is offering outstanding employment opportunities to qualified aeronautical design engineers. Many outstanding employee benefits and advancement possibilities are available in this extremely progressive organization. Direct your inquiries to Kevin Keelaghan, Assistant Chief Engineer, Lear, Incorporated, Aircraft Engineering Division, Santa Monica Airport, Santa Monica, Calif.

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**Engineers**—Doak Aircraft Co., Inc., Torrance, Calif. (Los Angeles County), has a number of unusually interesting openings for aeronautical engineers in the design and development of a new vertical take-off aircraft. Challenging opportunities for men with experience and training in the fields of aerodynamics, structural design, stress analysis, mechanical design, and engineering drafting. The development of this VTOL aircraft is being conducted under a prime Government contract. Please send résumé including salary requirements to N. E. Nelson, Chief Engineer, Doak Aircraft Co., Inc., 22309 South Western Avenue, Torrance, Calif.

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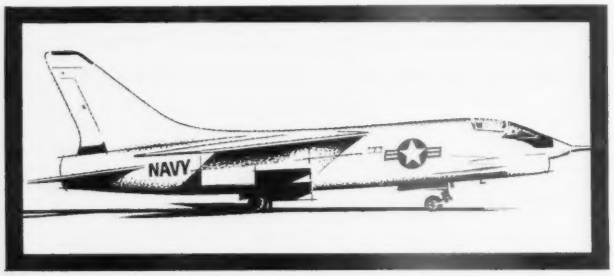


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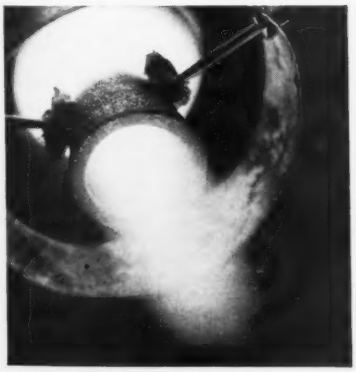

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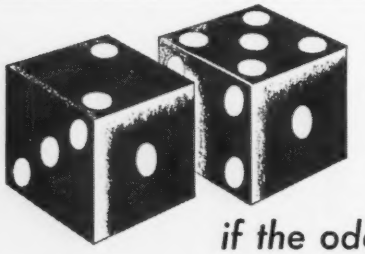

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**766. Professional Engineer**—B.Sc., with 25 years' experience, currently editor of a technical magazine in Canada, seeks editorial post. Offers scope for general engineering and scientific writing and first-class organizing ability. Age 51, British. Author of two books and scores of technical articles.

**765. Engineering Teaching Position**—With professorial rank desired in a private northeastern university. Fields of mechanics, thermodynamics, and heat transfer, etc. Ph.D. degree. Twelve years' experience in research, consulting, and teaching.

**761. Executive or Staff Engineer**—Adept at old or new problems in many fields. Can administer group or assist top executive in mechanical or related fields based on 20 years of integrated design, development, research, and management. Wide coverage of light to heavy mechanical activities including contract operations. Broad and progressive interests, registered, advanced degree.

**760. B-47 Aircraft Commander—Aeronautical Engineer**—Desires assignment as engineering test pilot. Diversified 3,000 hours conventional and jet; 900 hours B-47 First Pilot. Commercial single-engine land, single-engine sea, multiengine land, instrument ratings. Résumé on request.

**759. Aeronautical Engineer**—Presently employed by aircraft manufacturer. Desires position with air line in operations engineering with opportunity for advancement or participation in administration. East coast base preferred. B.Ae.E., M.M.E., private pilot rating; 5 years' total experience—2½ years' work with stability, control, and performance of guided missiles, and 3 years' experience in jet-aircraft research and development. Age 28.

**757. Technical Management Team**—Two-man team versed in basic science, engineering, and management. Experience in civilian and military technical organizations includes research, development, and production. M.Sc.E. and M.A. with postgraduate studies; specialists in aircraft and propulsion fields. Skilled in the application of systems concepts to management problems. Experienced in obtaining maximum efficiency in production through better utilization of engineering and technical personnel.

**756. Engineer—Administrator**—Diversified engineering background; specialist in aerothermodynamics. Would like a difficult job requiring initiative, intelligence, and the ability to coordinate group efforts. Excellent scientific background in modern aircraft and propulsion systems design. M.Sc.E. and over 15 years of experience in research, development, and design at working and supervisory levels. Primarily interested in obtaining results. Skilled in the effective utilization and development of personnel in scientific and engineering fields.

**755. Project Manager or Executive Assistant**—15 years' experience in aircraft and jet-engine industry. Three years as assistant to general manager of medium-size aircraft manufacturer. Extensive experience in project and contract administration. Good background in design and production engineering. Age 32. Desires position in western New York State or northeastern Ohio. Résumé on request.

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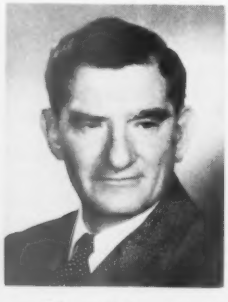

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# THE INSTITUTE OF THE AERONAUTICAL SCIENCES

## ITS PURPOSE

The Institute of the Aeronautical Sciences, established in 1932, is the representative society in America for professional engineers and specialists in all the sciences related to aeronautics. Its individual members form the nucleus of practically every aircraft and missile design and development project in the United States and abroad.

The basic mission of the Institute is to facilitate the exchange and evaluation of technical ideas among all engineers engaged in aeronautical work, wherever they may be. This is accomplished in two ways. First, the IAS maintains a carefully planned program of technical meetings, symposiums, and field trips to important aeronautical installations. Held on local, national, and international scales, IAS meetings provide an open forum for the testing and evaluation of new theories, new ideas, and new developments in every technical and scientific phase of aeronautics. Secondly, these meetings are supplemented by the official publications of the Institute, which serve to disseminate the results of new research and theory to engineering and scientific staffs in all parts of the world.

The Institute also maintains one of the finest research libraries on aeronautics in existence today. These facilities provide ready access to a source of technical information and specialized services of inestimable value to the aeronautical profession and the industry.

Through such active interchange of information, the Institute services the technical needs of one of the world's most exacting professional groups. Its only objective is the advancement of the arts and sciences of aeronautics.

## IAS MEMBERSHIP

To be elected to membership in the Institute of the Aeronautical Sciences is an honor and privilege. Applicants are carefully graded upon the recommendations of members. They are then considered by a Membership Committee, and the new members are elected to those grades of membership to which their experience, qualifications, and contributions entitle them.

An important function of the Institute has been, from its beginning, to give recognition to achievement in aeronautics and to encourage outstanding work in its related technical fields. The Institute honors those who have "attained a position of distinction and made notable or valuable contributions in one of the aeronautical sciences or aeronautical engineering" by the annual presentation of Honorary Fellowship and Fellowship awards.

It also presents various awards and certificates of citation to those individual pilots, engineers, and scientists who make the most notable contributions to the advancement of aeronautics, aviation medicine, and aerology each year.

Since the Institute's membership is composed largely of those individuals and firms who have developed the aeronautical sciences to their present-day levels, the foremost privilege offered any member is the advantage of association, contact, and collaboration with such members in a mutuality of interests and purposes. Through national and local Section meetings, organized and supervised by the Institute, personal contacts and exchange of ideas are afforded to IAS members.

## IAS MEETINGS

The Institute holds two general meetings annually, one in New York in January (4–5 days of Technical Sessions, plus the Honors Night Dinner) and one in Los Angeles in summer (3–4 days of Technical Sessions, plus field trips and a dinner). Other more specialized meetings are also scheduled. In 1955–1956 there were the following additional events:

(1) CAI-IAS Joint International Meeting, Ottawa, Ont., Canada, November 3–4, 1955.
(2) Inspection tour of WADC, Wright-Patterson AFB, Ohio, November 9–10, 1955.
(3) Nineteenth Wright Brothers Lecture, Washington, D.C., December 17, 1955.
(4) Eleventh Annual Flight Propulsion Meeting (with NACA), Cleveland, March 9, 1956.
(5) ASME-ARS-IAS Conference on Air Cargo & Air Logistics and on Thermal Barrier, Los Angeles, March 14–16, 1956.
(6) National Conference on Aeronautical Electronics, jointly with IRE, Dayton, Ohio, May 14–16, 1956.
(7) Turbine-Powered Air Transportation Meeting, San Diego, Calif., August 15–17, 1956.
(8) National Telemetering Conference, jointly with AIEE, IRE, and ISA, Chicago, August 20–21, 1956.

In addition to the IAS National Meetings, the 27 local Sections held over 270 technical meetings during the year. During the same period, our 74 Student Branches held some 450 meetings.

## IAS LIBRARY SERVICES

Since its inception, the IAS has recognized the value of a comprehensive, up-to-date library to the aeronautical engineer and scientist. Through the library, he has access to the vast body of aeronautical knowledge—the record of advances in the aeronautical sciences and the results of theoretical and experimental investigations.

The IAS Library in New York maintains an extensive collection spanning many years of aeronautical research and development. More than 8,000 technical books,

5,000 volumes of periodicals, and 50,000 reports are indexed and cataloged. An active acquisition program constantly brings in new publications from many countries, in many languages.

Through a liberal circulation policy, many thousands of reports and periodicals, as well as books, are loaned by mail each year to Individual and Corporate Members. Photocopy facilities are available for those who need retention copies, and the Library's specialized reference tools provide access to literature on many subjects.

A competent staff of editors and abstracters scans all current publications for prompt abstracting in the International Aeronautical Abstracts, Aeronautical Reviews, and Books sections of the AERONAUTICAL ENGINEERING REVIEW. Annually, these sections are cumulated into the AERONAUTICAL ENGINEERING INDEX.

The Pacific Aeronautical Library in Los Angeles provides its subscribers with interlibrary loan and reference services. It also issues a periodical and report index, available at cost to subscribers.

## IAS PUBLICATIONS

In addition to its monthly technical periodicals, the AERONAUTICAL ENGINEERING REVIEW and the JOURNAL OF THE AERONAUTICAL SCIENCES, the Institute publishes annually the AERONAUTICAL ENGINEERING CATALOG, the AERONAUTICAL ENGINEERING INDEX, and a ROSTER OF MEMBERS. It also publishes the Proceedings of special meetings.

The REVIEW contains aeronautical news; papers on applied engineering and aircraft production; and abstracts of articles, reports, and new books. The JOURNAL publishes scientific papers on new research and developments in all fields applied to aeronautics. The CATALOG is a guide to the manufacturers of all aircraft and guided missile products.

Through the Sherman M. Fairchild Publication Fund, the IAS publishes specialized technical reports

and selected preprints of papers presented at regular Institute meetings.

A number of publications designed to advance student interest and knowledge in the Aeronautical Sciences have been issued by the IAS under the auspices of the Minta Martin Aeronautical Student Fund and the Giannini Film Library Fund.

## IAS BUILDINGS

The Institute's building on Fifth Avenue, New York, overlooking Central Park, provides facilities worthy of the profession it serves. It houses the IAS libraries and museum collections, together with a staff to handle the Institute's many services.

Completed in 1949, buildings in Los Angeles and San Diego, Calif., provide auditoriums, meeting rooms, libraries, and other conveniences desirable for the activities of any scientific society. The western office of the Aircraft Industries Association and the Los Angeles office of the NACA are located in the Institute's western headquarters building in Los Angeles.

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Los Angeles

San Diego

# IAS MEMBERSHIP REQUIREMENTS

## Excerpts from By-Laws

### Article I—Membership

SECTION 1. All persons engaged in the practice of the aeronautical sciences or in other work which contributes to the advancement of the aeronautical sciences shall be eligible in one of the grades of membership of the Institute. Consideration in grading is given to professional education and experience, publications, academic position, membership in other scientific and engineering societies, record of aeronautical designs created and contributions to scientific knowledge. A Bachelor's Degree in science or engineering shall be considered the equivalent of four years of aeronautical experience. All applicants must sign, before admission, an agreement that they will conform to the Constitution, By-Laws, and Rules of the Institute.

SECTION 5. A Fellow shall have been an Associate Fellow for one year or more and have attained a position of distinction in aeronautics. He shall have made notable and valuable contributions in one of the aeronautical sciences or in aeronautical engineering. Not more than ten Fellows residing in the United States and ten Fellows residing in foreign countries may be elected each year by vote of the Honorary Fellows and Fellows by secret mail ballot under rules prescribed by the Council. Fellows shall be proposed and elected by the Honorary Fellows and Fellows of the Institute residing in the United States. A favorable vote of three-fourths of those voting shall be required for election.

SECTION 6. An Associate Fellow shall have been engaged for not less than ten years in the practice of the aeronautical sciences; and shall have been in responsible charge of important scientific or engineering work in aeronautics, or shall have done original work of outstanding character, or shall have otherwise made outstanding contributions to the aeronautical sciences. Applicants for this grade shall be recommended by not less than four members of the Institute of whom two or more shall be Fellows or Associate Fellows.

SECTION 7. MEMBERS shall be persons who have been engaged in professional work for at least eight years and have acquired a recognized standing in engineering, design, research, instruction, test flying, the application of the aeronautical sciences, or the technical development of the manufacture or operation of aircraft, aircraft power plants or other essential components or accessories of aircraft. To qualify for this grade applicants shall be recommended by not less than four persons of whom not less than two shall be members of the Institute.

SECTION 8. Associate Members shall be persons engaged in the application or development of aeronautics in administrative or other positions and who have acquired a recognized standing in aeronautics. Applicants for this grade shall be recommended by not less than four persons of whom not less than two shall be members of the Institute.

SECTION 10. Technical Members shall be former Student Members who have graduated and others engaged in scientific or engineering work in aeronautics or fields closely related to aeronautics. To qualify for this grade applicants shall be recommended by not less than four persons, one of whom shall be a member of the Institute.

SECTION 11. Student Members shall be undergraduate or graduate students attending those universities or schools where branches of the Institute have been organized. Student Members shall comply with, and be subject to, the Rules for Student Membership adopted by the Council.

SECTION 14. Honorary Fellows, Fellows, Honorary Members, Associate Fellows, MEMBERS and Associate Members shall be entitled to vote at meetings of the Institute, if in good standing. Proxies authorizing a voting member to vote for an absent member shall be signed by such absent member and shall be submitted to the Secretary in advance of the meeting for verification of the member's right to vote.

### Article II—Dues

SECTION 1. An entrance fee of Ten Dollars shall be payable on election to the grades of Technical Member, Associate Member, MEMBER or Associate Fellow, except that no entrance fee shall be payable by an applicant residing permanently outside the United States and Canada or by a Student Member applying, within the prescribed time limit, for admission as a Technical Member.

SECTION 2. The annual dues shall be:

| | |
|---|---|
| Fellows | $16.50 |
| Associate Fellows | 16.50 |
| MEMBERS | 13.50 |
| Associate Members | 13.50 |
| Technical Members over age 26 | 13.50 |
| Technical Members under age 26 | 6.50 |
| Student Members | None |

Dues shall include, except for Student Members, subscription to the AERONAUTICAL ENGINEERING REVIEW. Student Members may subscribe for the REVIEW at one-half the regular subscription rate. All members of the Institute residing in the United States and Canada may subscribe for the JOURNAL OF THE AERONAUTICAL SCIENCES at a special rate set by the Council.

For members residing permanently outside the United States and Canada annual dues shall be $10.00 in all grades and shall include subscription to the AERONAUTICAL ENGINEERING REVIEW and the JOURNAL OF THE AERONAUTICAL SCIENCES.

Beginning on the first of October next following his 26th birthday dues of a Technical Member shall be the same as those of a MEMBER.

# IAS HONORS AND AWARDS

## Honorary Fellows

*Honorary Fellows shall be persons of eminence in aeronautics and are elected by the Fellows and Honorary Fellows of the Institute residing in the United States. No more than one person residing in the United States, nor more than one person residing in a foreign country, may be elected as Honorary Fellow in any one year.*

J. Ackeret
Joseph S. Ames (Deceased)
Henry H. Arnold (Deceased)
Preston R. Bassett
Frank W. Caldwell
Ralph S. Damon (Deceased)
Sir Geoffrey de Havilland
Walter S. Diehl
James H. Doolittle
Donald W. Douglas
Hugh L. Dryden
W. F. Durand
Sir Richard Fairey
Sir Wm. S. Farren
Sir Roy Fedden
Lester D. Gardner
Leroy R. Grumman
Sir Frederick Handley Page
J. C. Hunsaker
Sir B. Melvill Jones
J. H. Kindelberger
George W. Lewis (Deceased)
Glenn L. Martin (Deceased)
Peter G. Masefield
George J. Mead (Deceased)
Clark B. Millikan
J. H. Parkin
J. Laurence Pritchard
Sir David Pye
Arthur E. Raymond
Igor I. Sikorsky
Sir Richard V. Southwell
Sir Geoffrey Taylor
Sir Henry Tizard
Th. von Kármán
Charles C. Walker
Edward Warner
Orville Wright (Deceased)
T. P. Wright

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## The Octave Chanute Award

*This award was established by the Institute in 1939 to honor the memory of Octave Chanute, pioneer American aeronautical investigator, who died in 1910. It is presented annually for a notable contribution made by a pilot to the aeronautical sciences.*

1939—Edmund T. Allen (Deceased)
1940—Howard Hughes
1941—Melvin N. Gough
1942—Albert Lewis MacClain
1943—William Henry McAvoy
1944—Colonel Benjamin S. Kelsey
1945—Robert T. Lamson and A. Elliott Merrill
1946—Ernest A. Cutrell
1947—Lawrence A. Clousing
1948—Herbert H. Hoover (Deceased)
1949—Captain Frederick M. Trapnell
1950—Commander Donald Bertram MacDiarmid
1951—Lieutenant Colonel Marion E. Carl
1952—John C. Seal
1953—William B. Bridgeman
1954—George E. Cooper
1955—Major General Albert Boyd
1956—A. M. Johnston

## The John Jeffries Award

*Honoring the memory of Dr. John Jeffries, an American physician who, with Blanchard, the French balloonist, made the first aerial voyage across the English Channel in 1785 and on a previous voyage made the earliest recorded scientific observation from the air, this award was established by the Institute in 1940 to give recognition to the importance to aviation of scientific endeavor in the field of medicine. It is presented annually for outstanding contributions to the advancement of aeronautics through medical research.*

1940—Dr. Louis H. Bauer
1941—Major Harry G. Armstrong
1942—Dr. Edward C. Schneider
1943—Brigadier General Eugen G. Reinartz
1944—Air Marshal Sir Harold E. Wittingham
1945—Commodore John C. Adams
1946—Brigadier General Malcom C. Grow
1947—Dr. J. Winfred Tice
1948—Dr. W. Randolph Lovelace, II
1949—Dr. Arnold D. Tuttle (Deceased)
1950—Brigadier General Otis O. Benson, Jr.
1951—Captain John R. Poppen
1952—Lieutenant Colonel John P. Stapp
1953—Captain Charles F. Gell
1954—Dr. James P. Henry
1955—Captain Wilbur E. Kellum

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## The Robert M. Losey Award

*Established in 1940, this award honors the memory of Capt. Robert Moffatt Losey, a member of the Institute and a meteorologic officer of the Air Corps, who was killed at Dombas, Norway, April 21, 1940, while serving as an official observer for the U.S. Army. He was the first officer in the service of the United States to die in World War II. It is presented annually in recognition of outstanding contributions to the science of meteorology as applied to aeronautics.*

1940—Henry Garrett Houghton, Jr.
1941—Horace Robert Byers
1942—Francis Wylton Reichelderfer
1943—Lieutenant Colonel Joseph J. George
1944—John Cary Bellamy
1945—Major Harry Wexler
1946—Carl G. Rossby
1947—Colonel Benjamin G. Holzman
1948—Paul A. Humphrey
1949—William Lewis
1950—Roscoe R. Braham, Jr.
1951—Ivan R. Tannehill
1952—Vincent J. Schaefer
1953—Henry T. Harrison, Jr.
1954—Hermann B. Wobus
1955—Lieutenant Colonel Robert C. Bundgaard

## The Sylvanus Albert Reed Award

*The late Dr. S. A. Reed, designer of metal aircraft propellers and a Founder Member of the Institute, made an endowment to the Institute in 1933 to provide an annual award to be presented for a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations which have had a beneficial influence on the development of practical aeronautics. The recipient of this award is chosen by ballot of the American Honorary Fellows and Fellows of the Institute.*

1934—C. G. Rossby and H. C. Willett
1935—Frank W. Caldwell
1936—Edward Story Taylor
1937—Eastman Nixon Jacobs
1938—Alfred Victor de Forest (Deceased)
1939—George J. Mead (Deceased)
1940—Hugh L. Dryden
1941—Th. von Kármán
1942—Igor I. Sikorsky
1943—Sanford A. Moss (Deceased)
1944—Fred E. Weick
1945—Charles S. Draper
1946—Robert T. Jones
1947—Galen B. Schubauer and Harold K. Skramstad
1948—George W. Brady
1949—George S. Schairer
1950—Robert R. Gilruth
1951—E. H. Heinemann
1952—John Stack
1953—Ernest G. Stout
1954—Clark B. Millikan
1955—H. Julian Allen

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## The Lawrence Sperry Award

*This award was endowed in 1936 by the sister and brothers of the late Lawrence Sperry, pioneer aviator and inventor, who died in 1923 at the age of 31. It is presented annually for a notable contribution made by a young man to the advancement of aeronautics.*

1936—William C. Rockefeller
1937—Clarence L. Johnson
1938—Russel C. Newhouse
1939—Charles M. Kearns, Jr.
1940—William B. Oswald
1941—Ernest G. Stout
1942—Edward C. Wells
1943—William B. Bergen
1944—William H. Phillips
1945—Richard Hutton
1946—Peter R. Murray
1947—Commander Noel A. M. Gayler
1948—Allen E. Puckett
1949—Alexander H. Flax
1950—Frank N. Piasecki
1951—Robert C. Seamans, Jr.
1952—Dean R. Chapman
1953—Donald Coles
1954—A. Scott Crossfield
1955—Giles J. Strickroth

## Wright Brothers Lecture

*The Wright Brothers Lecture is presented annually on December 17, the anniversary of the first airplane flight made by the Wright Brothers. It is endowed by the Vernon Lynch Fund and was established in 1937. The Lecturers are distinguished aeronautical scientists from this country and abroad.*

| | |
|---|---|
| B. Melvill Jones | Flight Experiments on the Boundary Layer |
| Hugh L. Dryden | Turbulence and the Boundary Layer |
| Clark B. Millikan | The Influence of Running Propellers on Airplane Characteristics |
| Sverre Pettersen | Recent Fog Investigations |
| Richard V. Southwell | New Pathways in Aeronautical Theory |
| Edmund T. Allen | Flight Testing for Performance and Stability |
| W. S. Farren | Research for Aeronautics—Its Planning and Application |
| John Stack | Compressible Flows in Aeronautics |
| H. Roxbee Cox | British Aircraft Gas Turbines |
| Th. von Kármán | Supersonic Aerodynamics—Principles and Applications |
| Sydney S. Goldstein | Low Drag and Suction Airfoils |
| Abe Silverstein | Research on Aircraft Propulsion Systems |
| A. E. Russell | Some Factors Affecting Large Transport Aeroplanes with Turboprop Engines |
| William Bollay | Aerodynamic Stability and Automatic Control |
| P. B. Walker | The Experimental Approach to Aircraft Structural Research |
| William Littlewood | Technical Trends in Air Transport |
| Glenn L. Martin | The First Half-Century of Flight in America |
| Bo Lundberg | The Fatigue Life of Airplane Structures |
| R. L. Bisplinghoff | Some Structural and Aeroelastic Considerations of High-Speed Flight |

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## Minta Martin National Awards

*This award is presented annually for the best technical papers given at IAS Regional Student Competitions.*

1955—David L. Cochran, Graduate Division
Voight R. Hodgson, Undergraduate Division

# IAS SECTIONS

*Sections of the Institute are operating in 27 centers of aeronautical activity in the United States. Local Institute activity provides for broader relationships among members and for the interchange of technical ideas through regularly scheduled meetings. The IAS Sections and their officers are listed below.*

### Atlanta

| | |
|---|---|
| *Chairman* | Arnold L. Ducoffe |
| *Vice-Chairman* | W. R. Rhodes |
| *Secretary* | E. S. Williams |
| *Treasurer* | Edith H. Lively |

### Baltimore

| | |
|---|---|
| *Chairman* | R. W. Sanford |
| *Vice-Chairman* | L. S. Jablecki |
| *Secretary* | R. G. Clanton |
| *Treasurer* | M. Duke |

### Boston

| | |
|---|---|
| *Chairman* | Edward L. Dashefsky |
| *Vice-Chairman* | John B. Tucker |
| *Secretary* | Daniel J. Fink |
| *Treasurer* | Eugene E. Larrabee |

### Chicago

| | |
|---|---|
| *Chairman* | Leland W. Sims |
| *Vice-Chairman* | Harry W. Wiant |
| *Secretary* | Robert F. Hunter |
| *Treasurer* | W. H. Tarbox |

### Cleveland-Akron

| | |
|---|---|
| *Chairman* | Bruce T. Lundin |
| *Vice-Chairman (Cleveland)* | Howard F. Powders |
| *Vice-Chairman (Akron)* | C. M. Bolster |
| *Secretary* | John C. Evvard |
| *Treasurer* | William A. Fleming |

### Columbus

| | |
|---|---|
| *Chairman* | Rudolph L. Tanck |
| *Vice-Chairman* | F. A. Wedberg |
| *Secretary* | F. L. Bagby, Jr. |
| *Treasurer* | Peter L. Marshall |

### Dayton

| | |
|---|---|
| *Chairman* | Gunther R. Graetzer |
| *Vice-Chairman* | T. J. Keating |
| *Secretary* | Walter E. Stanger |
| *Treasurer* | Frank E. Carroll |

### Detroit

| | |
|---|---|
| *Chairman* | Ludwig Majneri |
| *Vice-Chairman* | C. Vogel |
| *Secretary* | Fred J. Wilhoff |
| *Treasurer* | Richard Chute |

### Hagerstown

| | |
|---|---|
| *Chairman* | C. S. Huber |
| *Vice-Chairman* | J. A. Neilson |
| *Secretary* | R. W. Bradham |
| *Treasurer* | E. F. Kuklewicz |

### Hampton Roads

| | |
|---|---|
| *Chairman* | Richard E. Kuhn |
| *Vice-Chairman* | Lewis R. Fisher |
| *Corresponding Secretary* | Paul A. Hunter |
| *Recording Secretary* | Richard T. Whitcomb |
| *Treasurer* | Axel T. Mattson |

### Indianapolis

| | |
|---|---|
| *Chairman* | Robert E. Saff |
| *Vice-Chairman* | R. C. Binder |
| *Secretary* | John A. Duff |
| *Treasurer* | James D. Anderson |

### Los Angeles

| | |
|---|---|
| *Chairman* | Welko E. Gasich |
| *Vice-Chairman* | M. C. Haddon |
| *Secretary* | A. Carah |
| *Treasurer* | C. F. Sardou, Jr. |

### New York

| | |
|---|---|
| *Chairman* | Richard G. Bowman |
| *Vice-Chairman* | Nicholas J. Hoff |
| *Secretary-Treasurer* | C. H. S. Murphy |

### Niagara Frontier

| | |
|---|---|
| *Chairman* | James O'Malley |
| *Vice-Chairman* | David Whitcomb |
| *Secretary* | Ronal Crisman |
| *Treasurer* | Daniel Hardie |

### Philadelphia

| | |
|---|---|
| *Chairman* | Earle Stewart |
| *Vice-Chairman* | Harold Kaufman |
| *Secretary* | Marjorie Hecht |
| *Treasurer* | Frank Mamrol |

### Rocky Mountain

| | |
|---|---|
| *Chairman* | Vincent J. Bracha |
| *Vice-Chairman* | Alison M. Arnold |
| *Secretary* | Arthur W. Gilmore |
| *Treasurer* | William R. Fuchs |

### San Antonio

| | |
|---|---|
| *Chairman* | Claude W. Smith |
| *Vice-Chairman* | William C. Robinson |
| *Secretary* | Joseph Draper |
| *Treasurer* | Raymond J. Tolosko |

### San Diego

| | |
|---|---|
| *Chairman* | Earl R. Hinz |
| *Vice-Chairman* | H. C. Matteson |
| *Corresponding Secretary* | D. P. Germeraad |
| *Recording Secretary* | R. A. Fuhrman |
| *Treasurer* | P. E. Culbertson |

### San Francisco

| | |
|---|---|
| *Chairman* | George E. Cooper |
| *Vice-Chairman* | Russell G. Robinson |
| *Secretary* | Jack A. Bert |
| *Treasurer* | Robert M. McIvers |

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| | |
|---|---|
| *Chairman* | L. T. Goodmanson |
| *Vice-Chairman* | R. E. Bateman |
| *Secretary* | T. V. Davis |
| *Treasurer* | M. E. Kirchner |

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| | |
|---|---|
| *Chairman* | J. F. Yardley |
| *Vice-Chairman* | L. A. Smith |
| *Corresponding Secretary* | W. J. Blatz |
| *Recording Secretary* | L. A. Perrin |
| *Treasurer* | D. W. Allen |

### Texas

| | |
|---|---|
| *Chairman* | R. J. Patton |
| *Vice-Chairman* | C. L. Turner, Jr. |
| *Secretary* | A. T. Clemen |
| *Treasurer* | E. H. Flath |

### Tullahoma

| | |
|---|---|
| *Chairman* | James B. Delano |
| *Vice-Chairman* | Robert LeBeck |
| *Secretary* | Gene H. Hull |
| *Treasurer* | Ray W. Harvey |

### Tulsa

| | |
|---|---|
| *Chairman* | Clark L. Marks |
| *Vice-Chairman* | Everett W. Garrison |
| *Recording Secretary* | Gertrude H. Fila |
| *Corresponding Secretary* | Richard M. Gilmore |
| *Treasurer* | R. B. Jenny |

### Twin Cities

| | |
|---|---|
| *Chairman* | Rudolph Hermann |
| *Vice-Chairman* | Thomas Chase |
| *Secretaries* | Herbert Johnson and Robert Holdahl |
| *Treasurer* | Art Jones |

### Washington, D.C.

| | |
|---|---|
| *Chairman* | Thomas L. K. Smull |
| *Vice-Chairman* | Alfred B. Metsger |
| *Secretary* | George T. Hayes |
| *Treasurer* | Gerald L. Desmond |

### Wichita

| | |
|---|---|
| *Chairman* | J. H. Gerteis |
| *Vice-Chairman* | S. H. Hinton |
| *Secretary* | E. J. Sullivan |
| *Treasurer* | P. A. Jackson |

# IAS STUDENT BRANCHES

*Three thousand Student Members of the IAS are served by the activities of Student Branches functioning in 74 colleges and universities. The Institute's student program augments the dissemination of technical knowledge and encourages professional consciousness among students of the aeronautical sciences. Student Branches and Faculty Advisers are listed below.*

| | |
|---|---|
| **Academy of Aeronautics** | Ivo J. Fioravanti |
| **The Aeronautical University** | Alfred F. Stott |
| **Agricultural & Mechanical College of Texas** | E. E. Brush |
| **Alabama Polytechnic Institute** | Robert G. Pitts |
| **Boston University** | Leonard J. Waxer |
| **Brown University** | Paul F. Maeder |
| **California Institute of Technology** | Max L. Williams, Jr. |
| **California State Polytechnic College** | Lester W. Gustafson |
| **Carnegie Institute of Technology** | Clarence M. Tyler, Jr. |
| **Case Institute of Technology** | Ray E. Bolz |
| **The Catholic University of America** | Eli Amanuel |
| **Cornell University** | Carlo Riparbelli |
| **Georgia Institute of Technology** | John J. Harper |
| **Harvard University** | Arthur E. Bryson |
| **Illinois Institute of Technology** | Stothe P. Kezios |
| **Indiana Technical College** | B. L. Dow |
| **Iowa State College** | E. W. Anderson |
| **The Johns Hopkins University** | G. L. Bryan |
| **Kansas State College** | Frank J. McCormick |
| **Kent State University** | Peder A. Otterson |
| **Louisiana State University** | E. E. Maser |
| **Massachusetts Institute of Technology** | James W. Mar |
| **Mississippi State College** | Franklin S. Edwards |
| **New York University** | Frederick K. Teichmann |
| **North Carolina State College** | Robert M. Pinkerton |
| **North Dakota Agricultural College** | Frederick W. Stuve |
| **Northrop Aeronautical Institute** | Richard Charles Smith |
| **The Ohio State University** | Sheng To Chu |
| **Oklahoma Agricultural and Mechanical College** | L. J. Fila |
| **Oregon State College** | H. D. Christensen |
| **Parks College of Aeronautical Technology** | Richard B. Trefny |
| **The Pennsylvania State University** | John A. Fox |
| **Polytechnic Institute of Brooklyn** | Joseph Kempner |
| **Princeton University** | David C. Hazen |
| **Purdue University** | P. E. Stanley |
| **Rensselaer Polytechnic Institute** | Hubert C. Mattice |
| **San Diego State College** | Charles Morgan |
| **San Jose State College** | John G. Allen |
| **Stanford University** | S. J. Kline |
| **Stevens Institute of Technology** | B. K. Erdoss |
| **Syracuse University** | Salamon Eskinazi |
| **Tri-State College** | Charles Libove |
| **University of Alabama** | Edward W. Geller |
| **University of California in Berkeley** | Lawrence Talbot |
| **University of California in Los Angeles** | Robert A. Needham |
| **University of Cincinnati** | Bradley Jones |
| **University of Colorado** | Franklin P. Durham |
| **University of Detroit** | Edward A. Szczepaniak |
| **University of Florida** | William H. Miller |
| **University of Illinois** | Harry H. Hilton |
| **University of Illinois in Chicago** | Fred W. Schroeder |
| **University of Kansas** | Ammon S. Andes |
| **University of Kentucky** | K. O. Lange |
| **University of Maryland** | George P. Maggos |
| **University of Michigan** | R. B. Morrison |
| **University of Minnesota** | A. E. Cronk |
| **University of Notre Dame** | F. N. M. Brown |
| **University of Oklahoma** | L. A. Comp |
| **University of Pittsburgh** | C. C. Yates |
| **University of Southern California** | V. J. Martin |
| **University of Texas** | M. J. Thompson |
| **University of Toledo** | A. A. Fejer |
| **University of Tulsa** | J. C. Klotz |
| **University of Utah** | Arlo F. Johnson |
| **University of Virginia** | James E. May |
| **University of Washington** | Raymond C. Weikel |
| **University of Wichita** | Everett L. Cook |
| **University of Wyoming** | Alfred B. Stafford |
| **U.S. Air Force Institute of Technology** | Harold C. Larsen |
| **U.S. Naval Academy** | C. W. Maier |
| **U.S. Naval Postgraduate School** | Richard M. Head |
| **Virginia Polytechnic Institute** | Robert W. Truitt |
| **Wayne University** | Joseph Rutkowski |
| **West Virginia University** | L. Z. Seltzer |

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Bartram Kelley
R. B. Maloy
Ralph McClarren
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W. L. Howland
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R. L. Bisplinghoff
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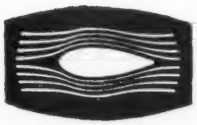

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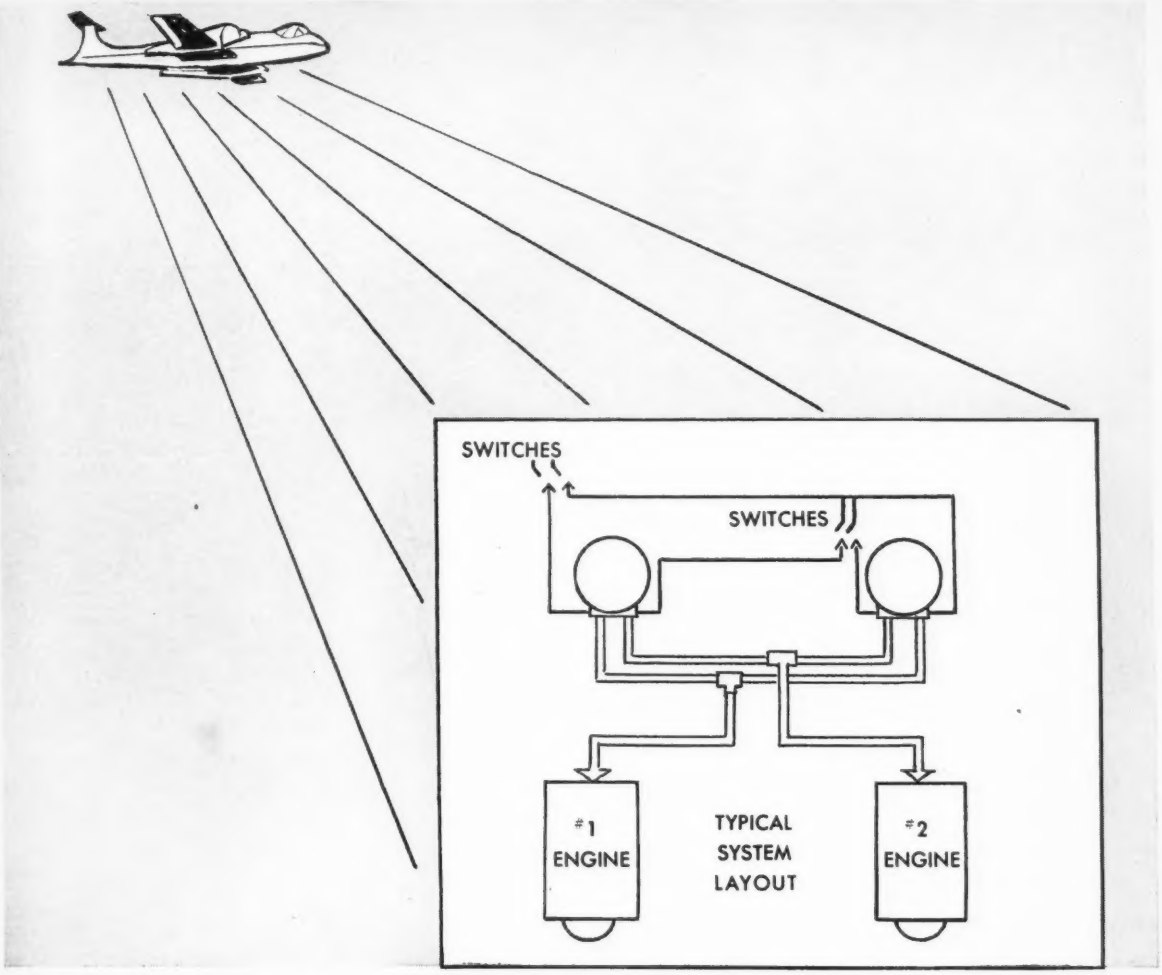


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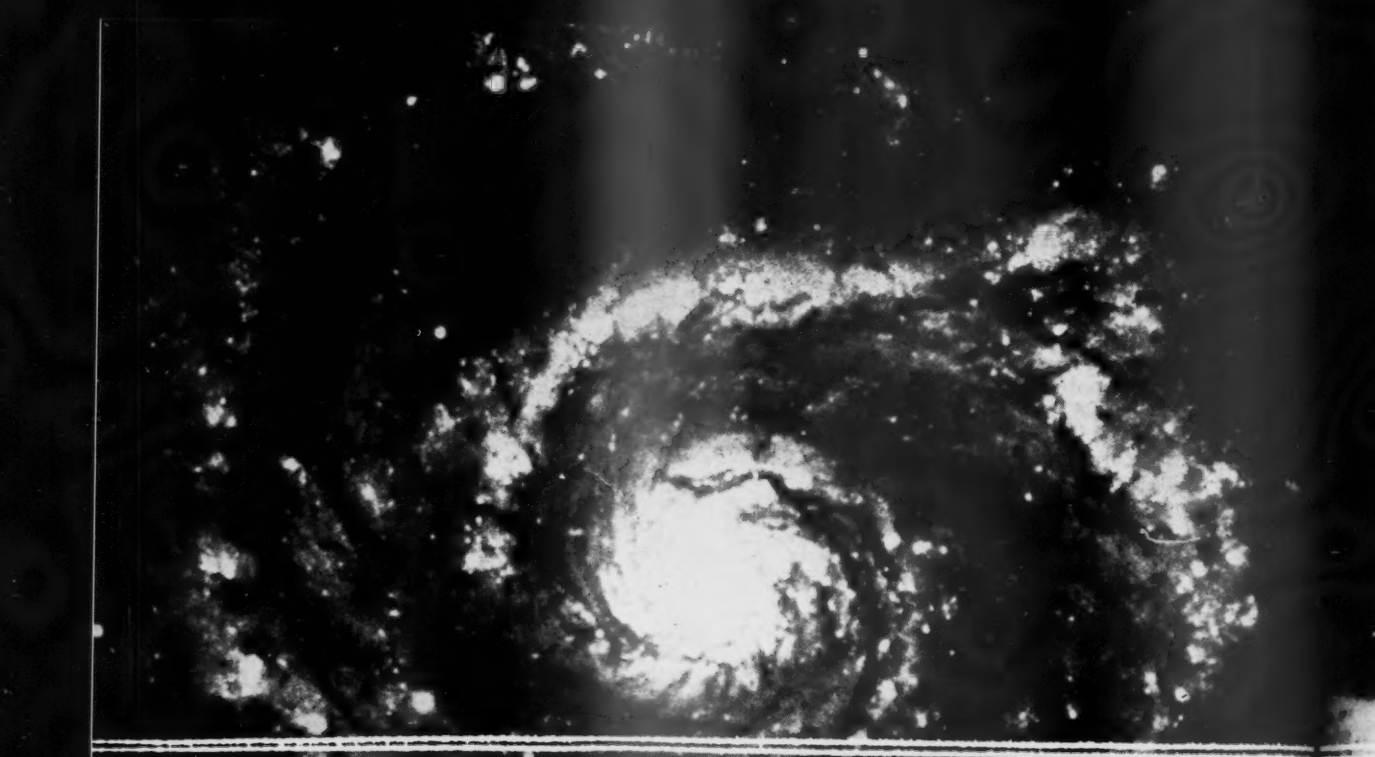

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**EEMCO Type D-899** is a compact, light weight 400 cycle, 3-phase motor with an integral gear box that operates on 200 volt power. It was designed by EEMCO especially for use in supersonic aircraft and missiles and meets MIL-M-7969-(ASG) specifications. Weighing only 11.25 pounds, it has a continuous output of 2.75 HP at 3140 RPM at the gear box. The power factor is 83% while the overall efficiency of the unit is 76%. Mounting flange is made to Spec. AND-20,000.

A feature in the design of **EEMCO Type D-899** is that the gear box acts as the motor support which places the base at approximately the center of gravity of the motor-pump assembly. This enables the unit to withstand the extreme shocks and vibrations encountered in supersonic aircraft and missiles. With minor alterations, the motor can be made splash- and drip-proof.

**Type D-899** is another example of the fine craftsmanship found in all EEMCO products. EEMCO's entire effort is confined to the design and production of linear and rotary actuators and special motors of high-output light-weight ratio. Many of the latest jet aircraft and missiles being developed or delivered carry EEMCO units. EEMCO products are also used for industrial applications where precise control tolerances are imperative.

**SPECIFICATIONS OF EEMCO TYPE D-899 MOTOR**

**Model:** 200 volt, 400 cycle, 3-phase.
**Load:** 2.75 HP continuous output.
**R.P.M.:** 3140 RPM output at gear box.
**Power Factor:** 83%
**Overall Efficiency:** 76% for entire unit.
**Military Specification:** Meets MIL-M-7969-(ASG).
**Weight:** 11.25 pounds.
**Comments:** Type D-899 may be made splash- and drip-proof with minor alterations.

**Designers and producers of motors, linear and rotary actuators... exclusively**

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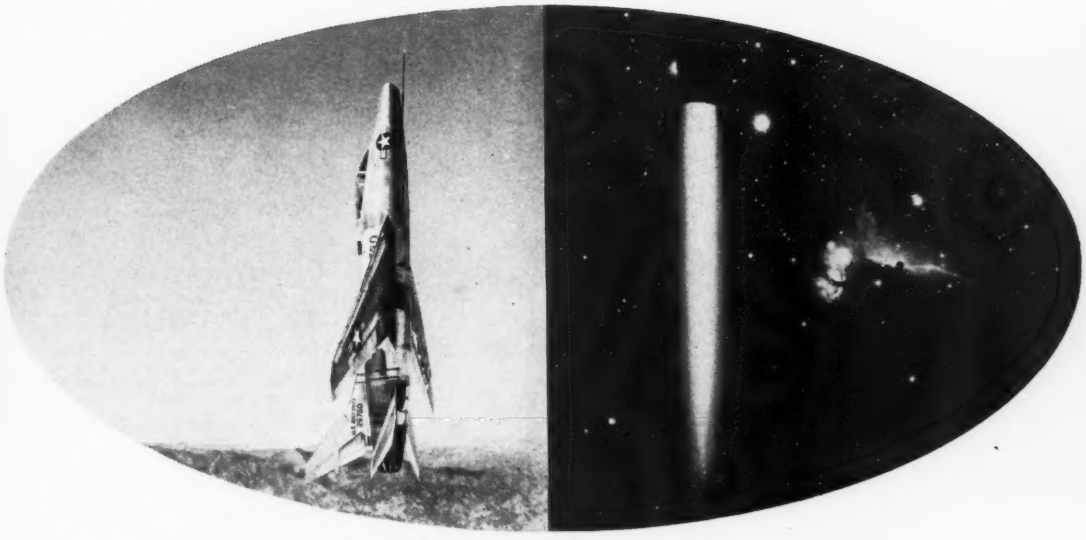

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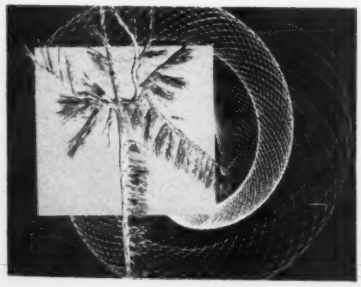

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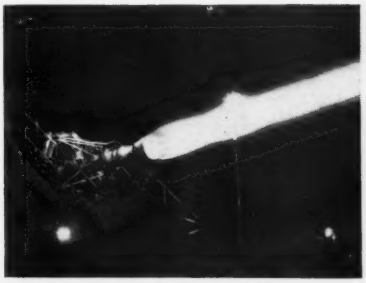

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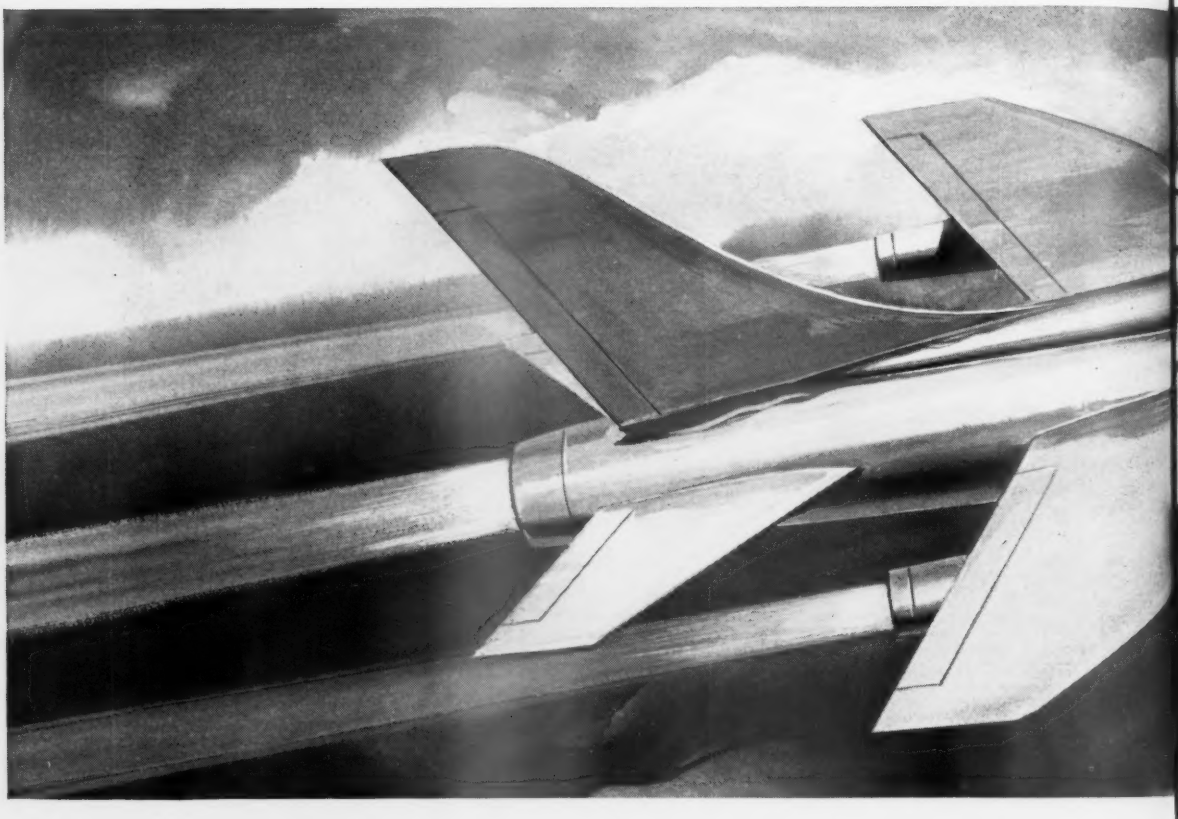

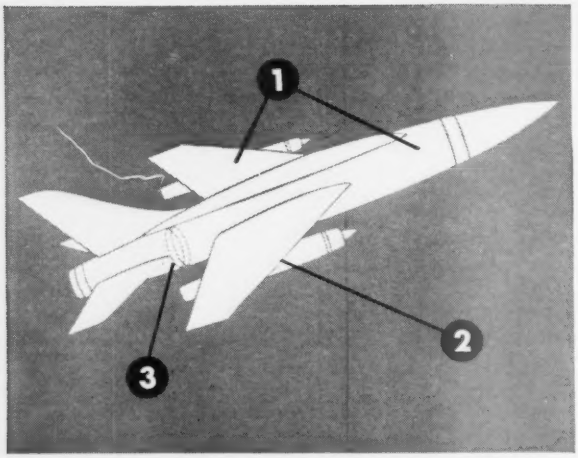


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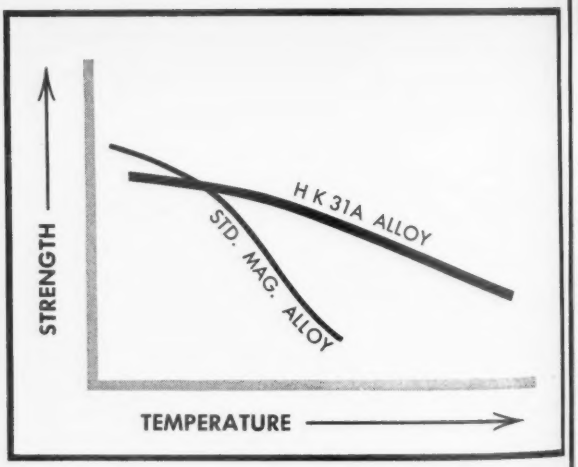


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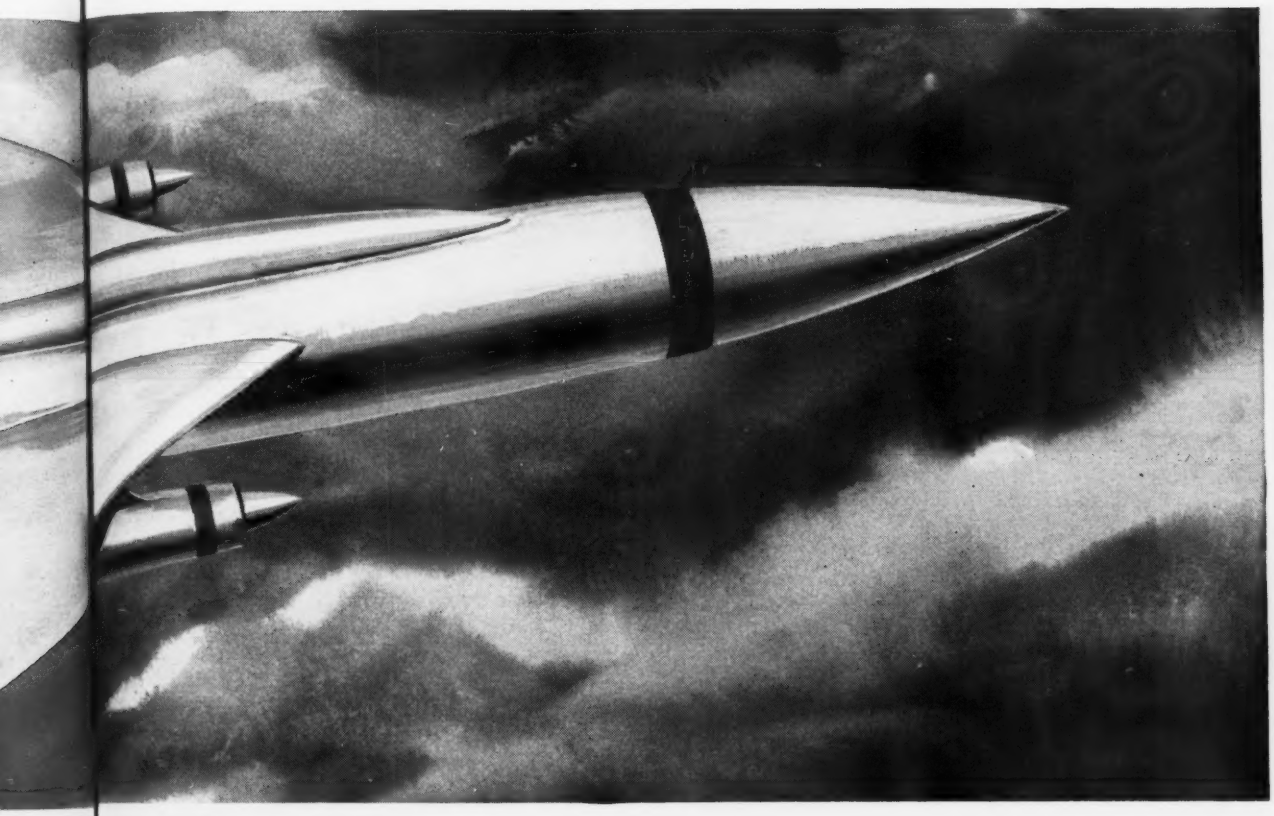

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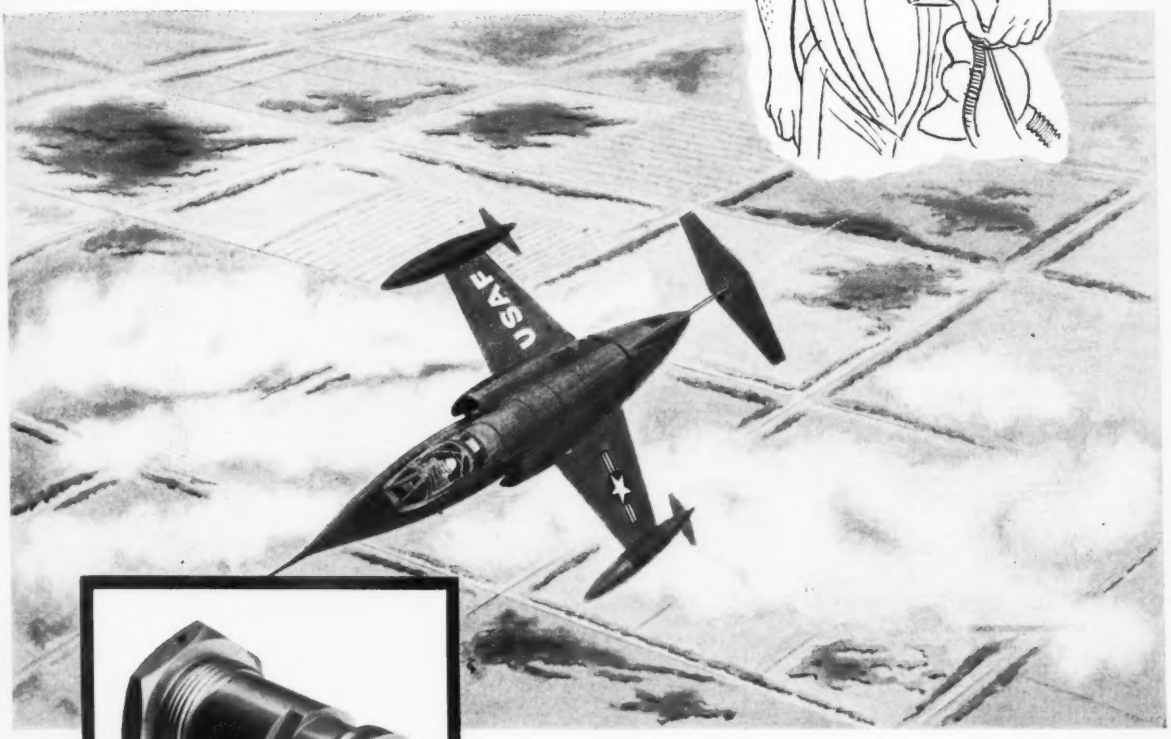


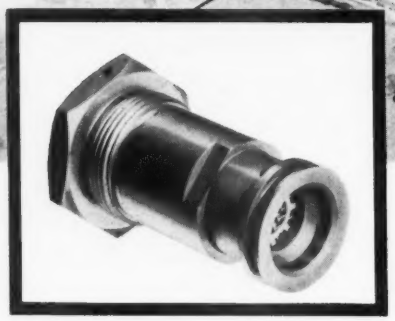

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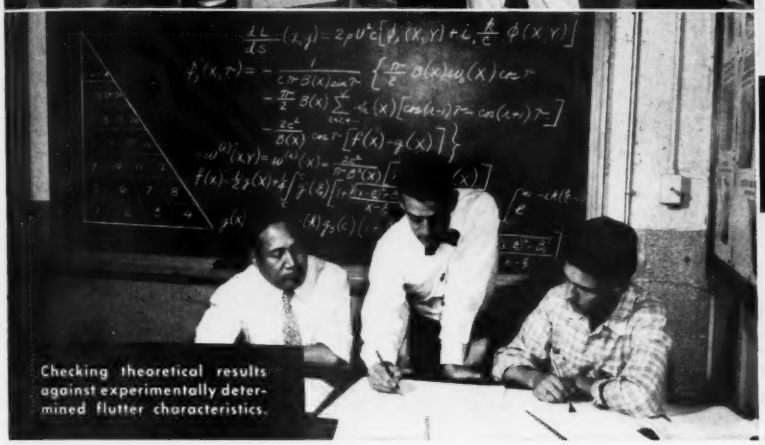
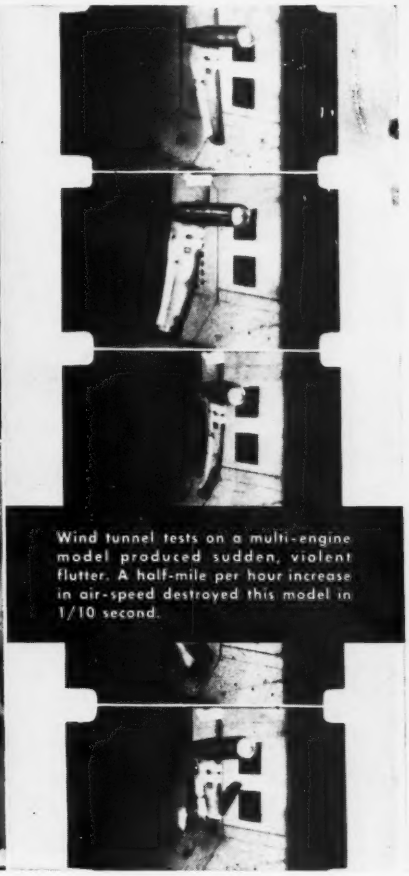
Determination of the Vibratory Characteristics of a 60° Delta Wing at zero airspeed.



Checking theoretical results against experimentally determined flutter characteristics.



Wind tunnel tests on a multi-engine model produced sudden, violent flutter. A half-mile per hour increase in air-speed destroyed this model in 1/10 second.

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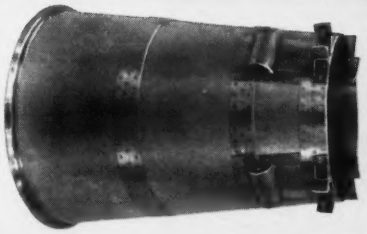

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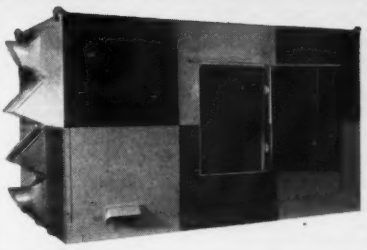

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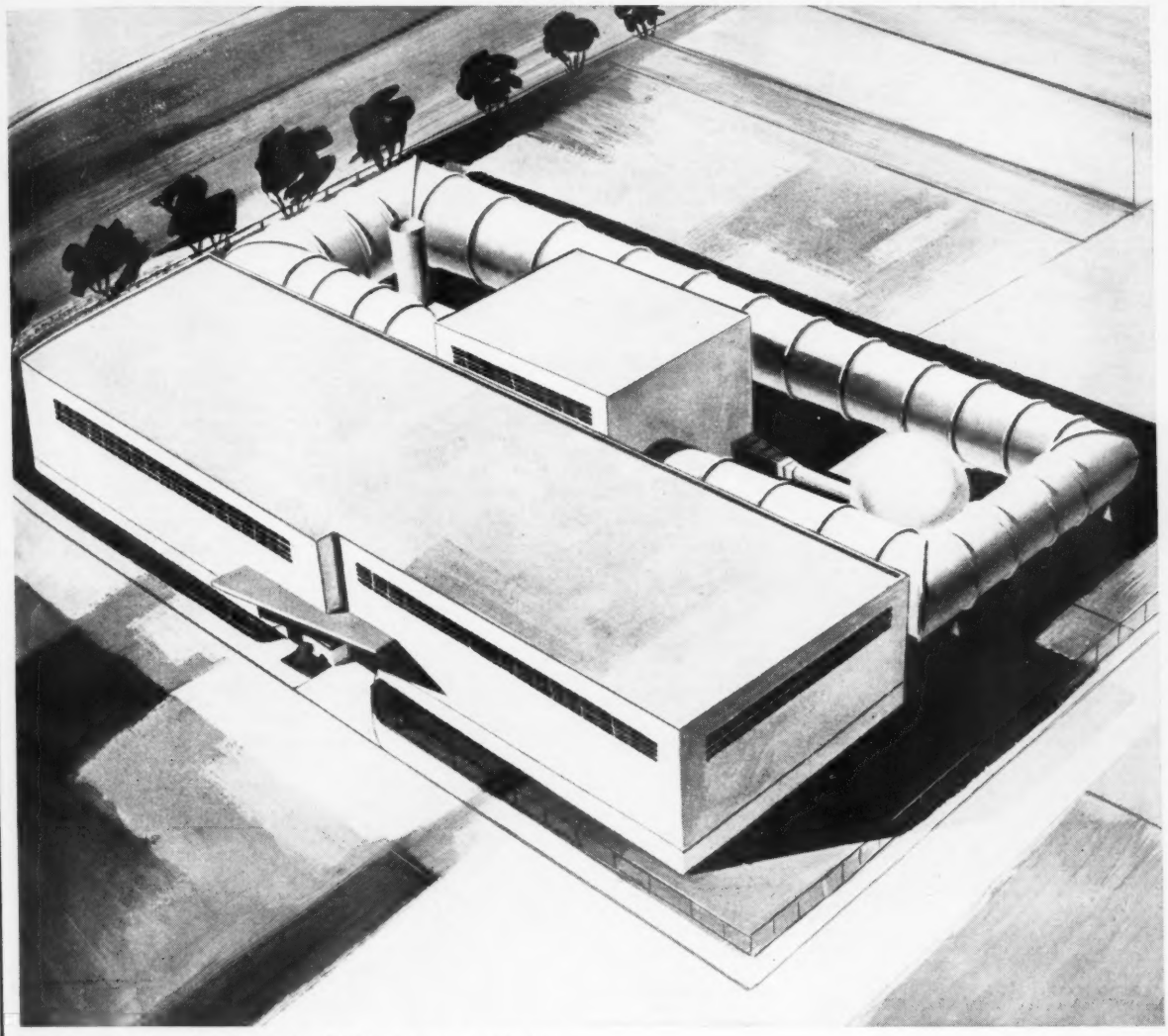

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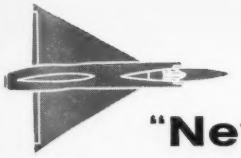

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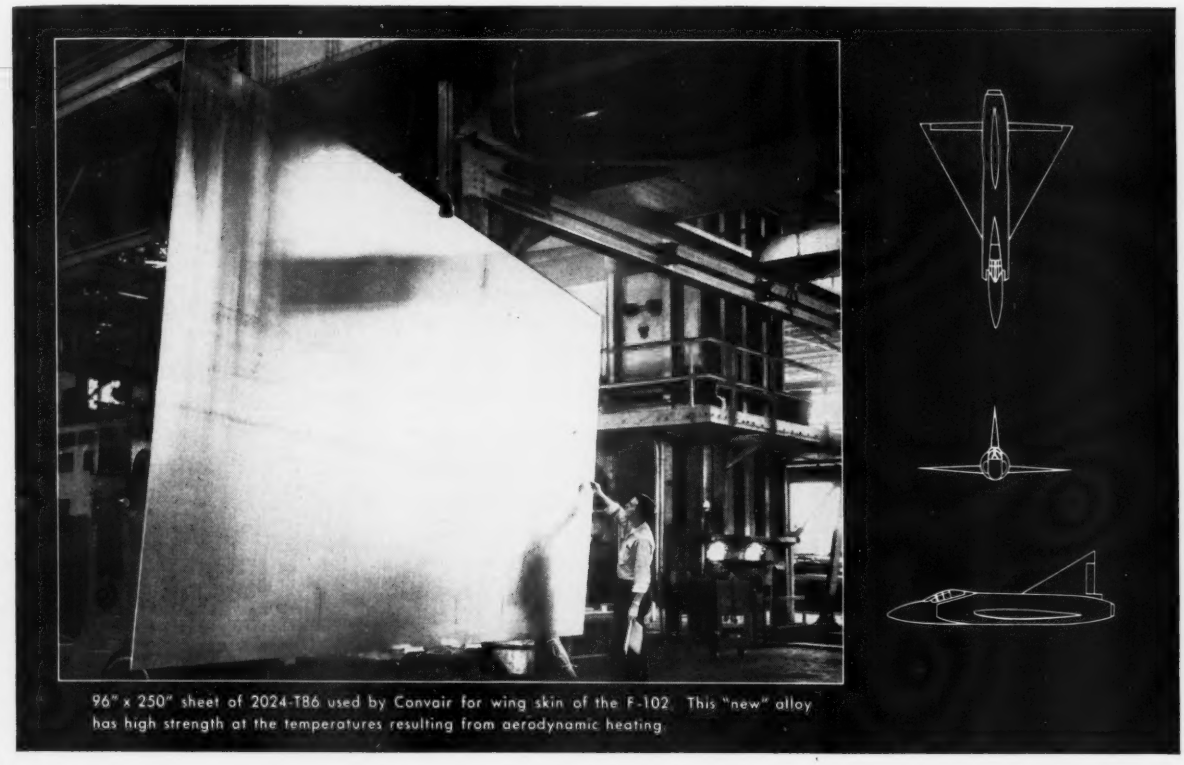

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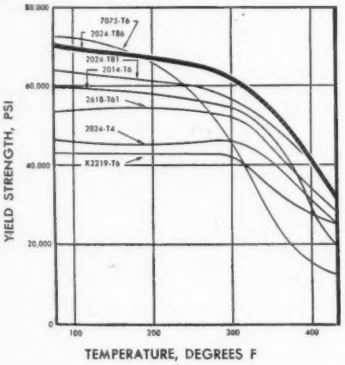


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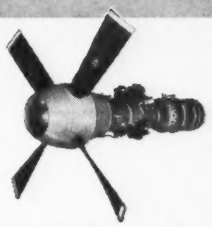

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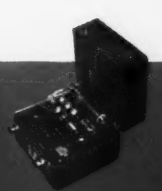

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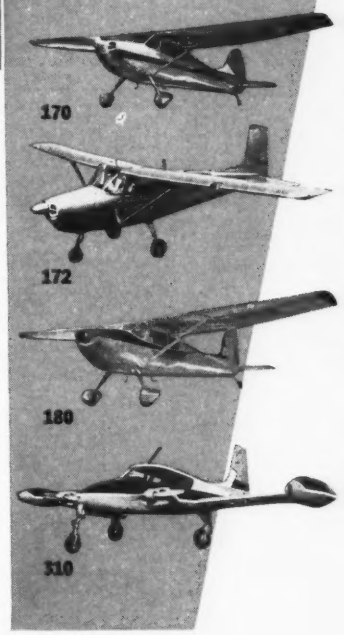

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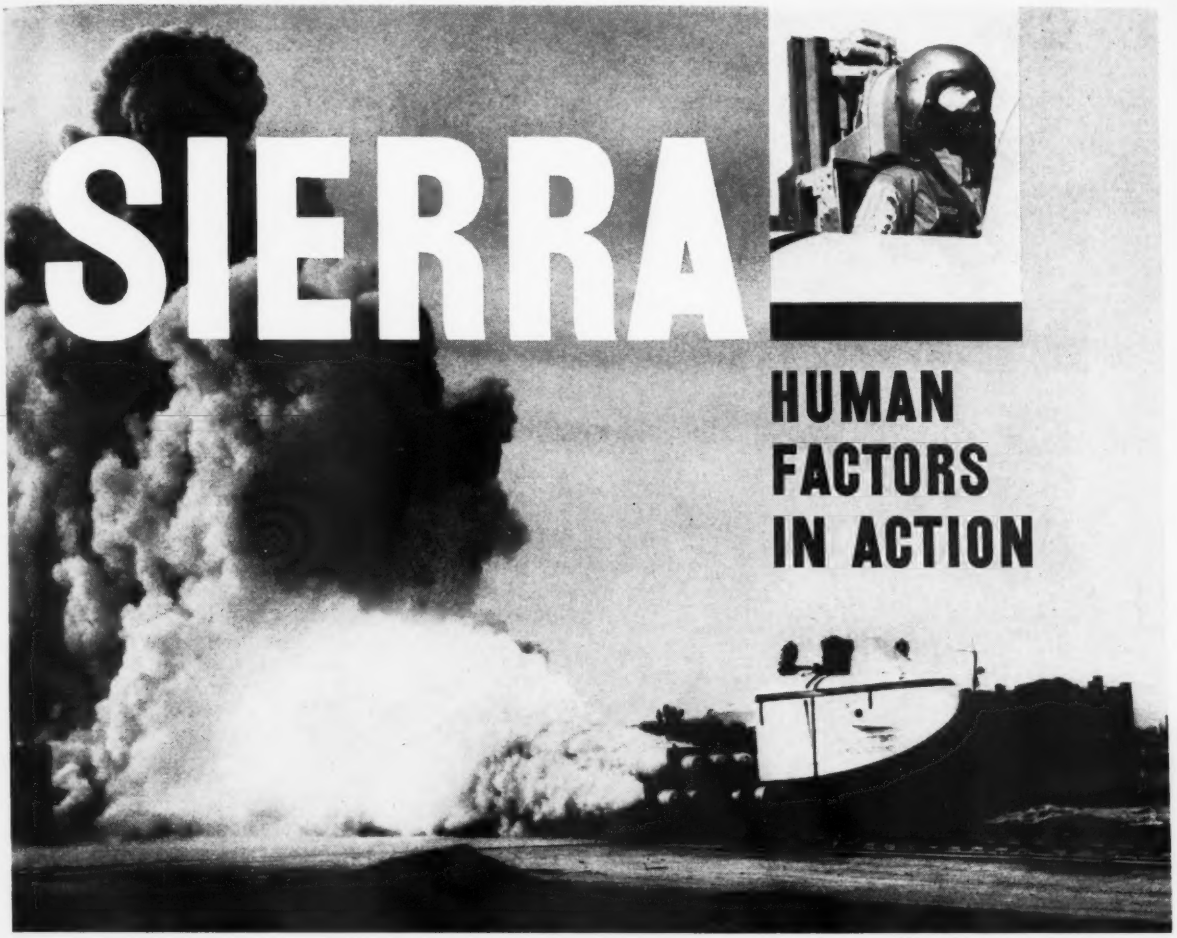


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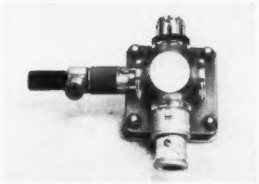

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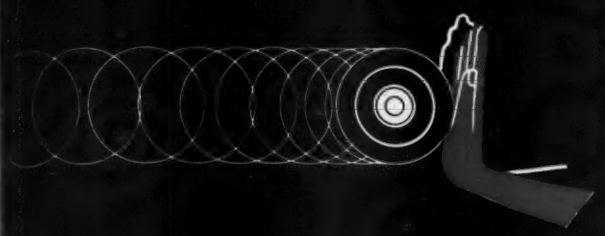

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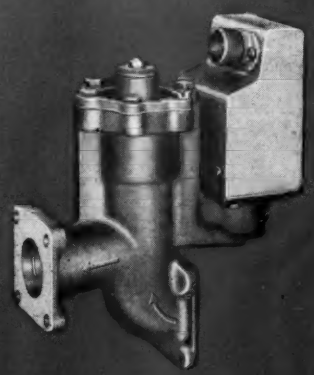

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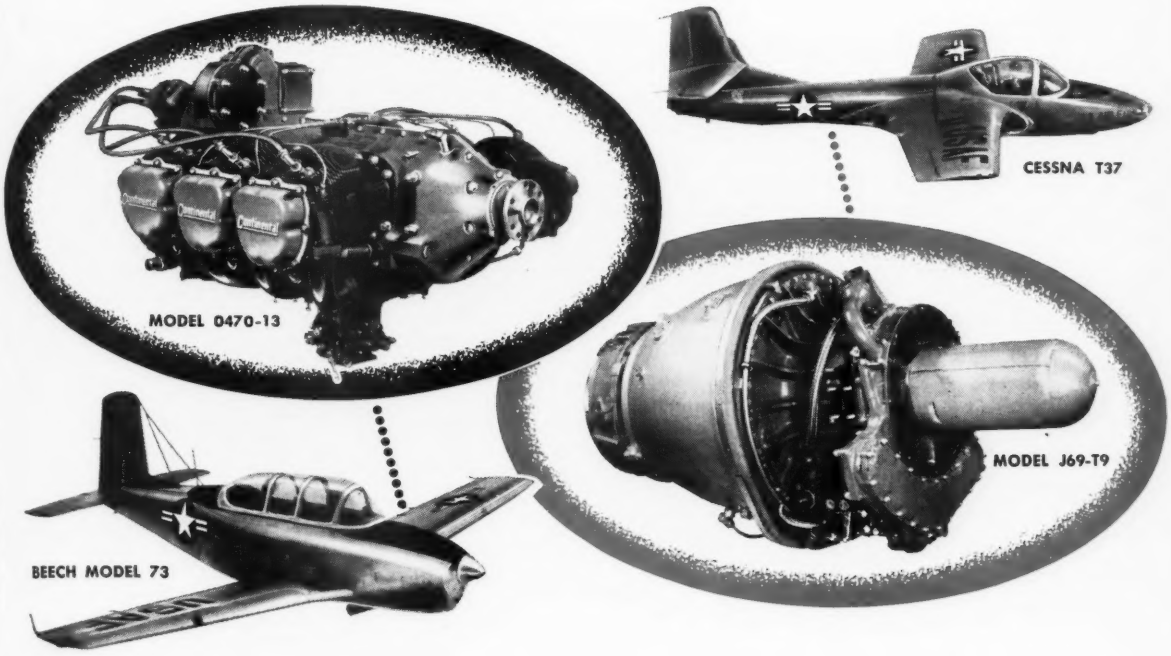


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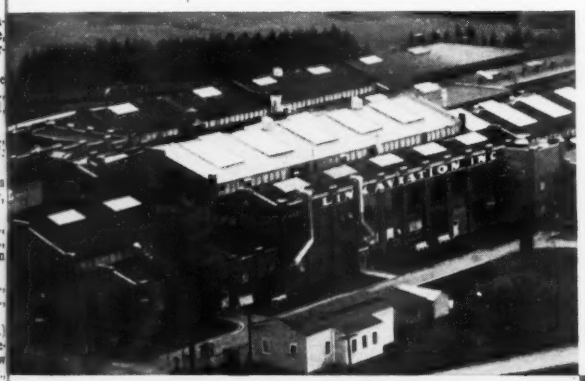


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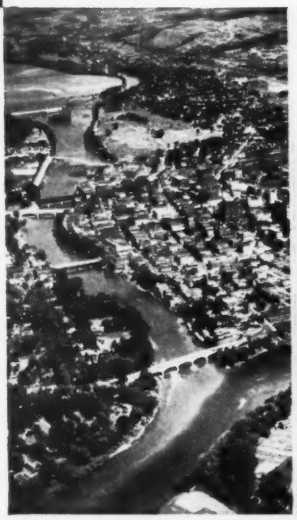

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## Jack & Heintz A-C System— Douglas DC-8 Jet Transport

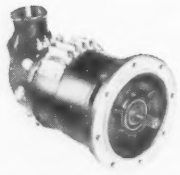
| COMPONENT | NO. PER AIRPLANE |
|---|---|
| 31008 Generator, 20 kva | 4 |
| 51202 Voltage Regulator | 4 |
| 50128 Control Panel | 4 |
| 50137 Power Relay | 8 |
| 50162 Current Transformer & Limiter Panel | 4 |
| 50130 Bus Protection Panel | 1 |
| 50124 Current Transformer (separate mtg) | 12 |

Total weight—all components—380 pounds.

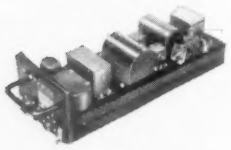
Jack & Heintz engineers and Douglas equipment section engineers discuss a-c system design at Santa Monica, Calif. Left to right, are: M. H. Peairs, electrical systems engineer, DAC; Peter Duyan, chief equipment section, DAC; Sid Webster, western district manager, J&H; A. W. Rebard, DC-8 group engineer, DAC; and Robert Sumner, field service representative, J&H.

# JACK & HEINTZ

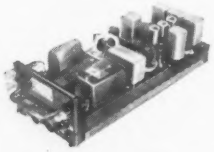
## AIRCRAFT ELECTRIC EQUIPMENT



J&H Model 31193 Generator†



J&H Model 51202 Voltage Regulator



J&H Model 50128 Control Panel

J&H Model 50137 Power Relay

**Generators:** rated 20 kva; meet Military Class C thermal requirements; will deliver 137½% rated power continuously for DC-8 operating conditions.

**Hi-Phase* Voltage Regulators:** protect against overvoltage from asymmetrical faults; provide accurate regulation with static components; utilize printed wiring.

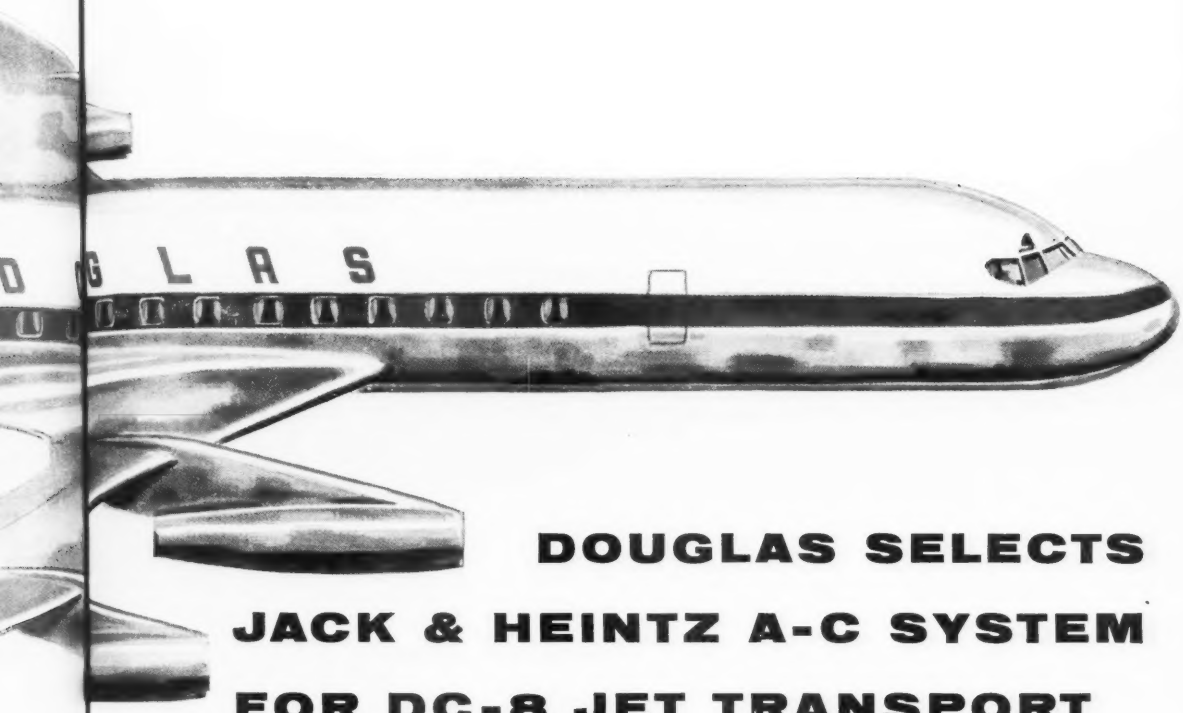
**Control Panels:** simple central wiring harness; unique overvoltage relays insensitive to acceleration and vibration.

**Power Relays:** feature mechanical phase isolation and easy maintenance.

Current Transformer & Limiter Panel and the Bus Protection Panel provide relaying, metering and load division functions.

†*Laboratory prototype for DC-8 system. This model is being superseded by J&H Model 31008 Generator.*

*T. M. applied for



# DOUGLAS SELECTS JACK & HEINTZ A-C SYSTEM FOR DC-8 JET TRANSPORT

## First A-C System Designed for Commercial Aviation

The a-c system designed by a team of Douglas and J&H engineers for the DC-8 is the first for a commercial airplane and incorporates in its design *tried and proved* principles in accordance with airline philosophy.

The ship-set components are simple in arrangement and automatic in operation.

### Simplicity, Safety and Reliability are System Features

The system is as simple to operate as present d-c systems with all components readily accessible for easy maintenance.

The installation is designed so that the possibility of fault is remote. However, if a fault should occur, it is isolated quickly and automatically. Power to loads is interrupted only to those circuits affected.

Co-ordinated mechanical and electrical designs result in long reliable service life for components.

### J&H Organization Proves Asset

Many factors were considered by Douglas in awarding the DC-8 a-c system contract. One primary factor in the selection of Jack & Heintz was its organization. Douglas considered it ideal for expeditious handling of an over-all system project. J&H conducts all research, development and production at *one* location, affording maximum engineering teamwork with minimum lost motion.

Important, too, is an intensive educational and maintenance support program which Jack & Heintz will offer the airlines to acquaint them with this new a-c system.

Whether your system problem is a-c or d-c, Jack & Heintz has the engineering know-how and complete facilities to meet your needs. Write Jack & Heintz, Inc., 17632 Broadway, Cleveland 1, Ohio. Export Department: 13 E. 40th Street, New York 16, N. Y.

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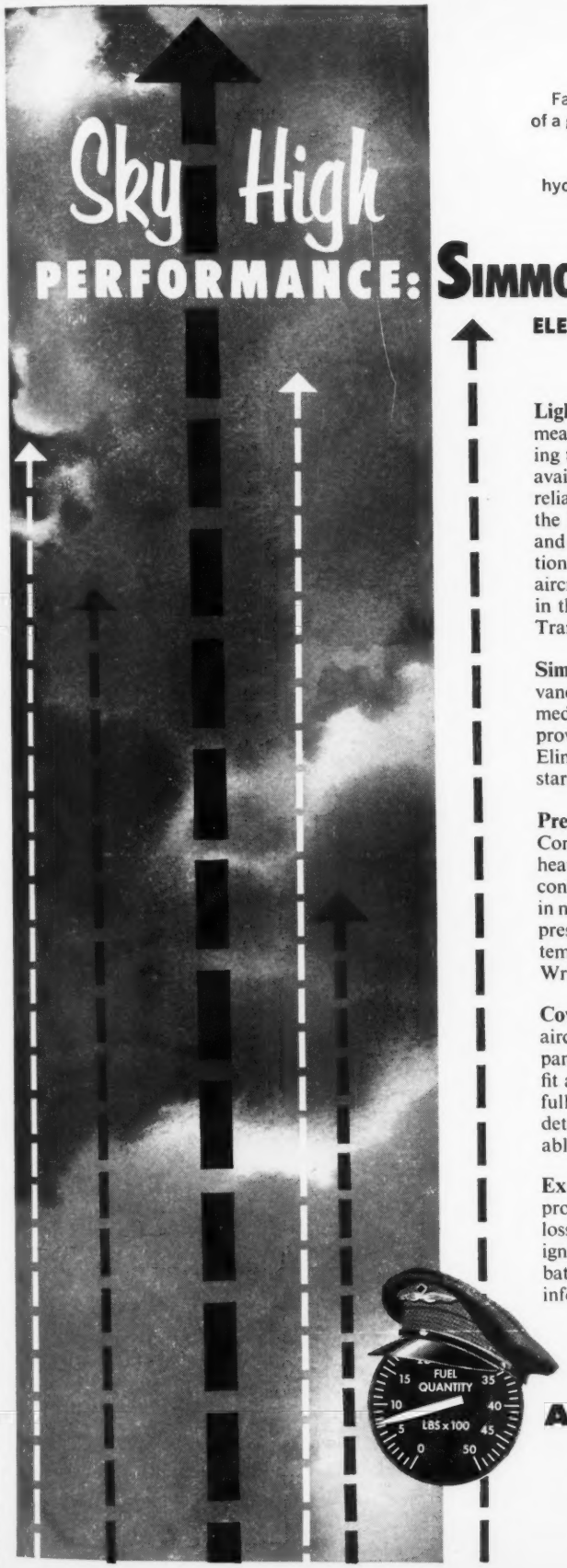


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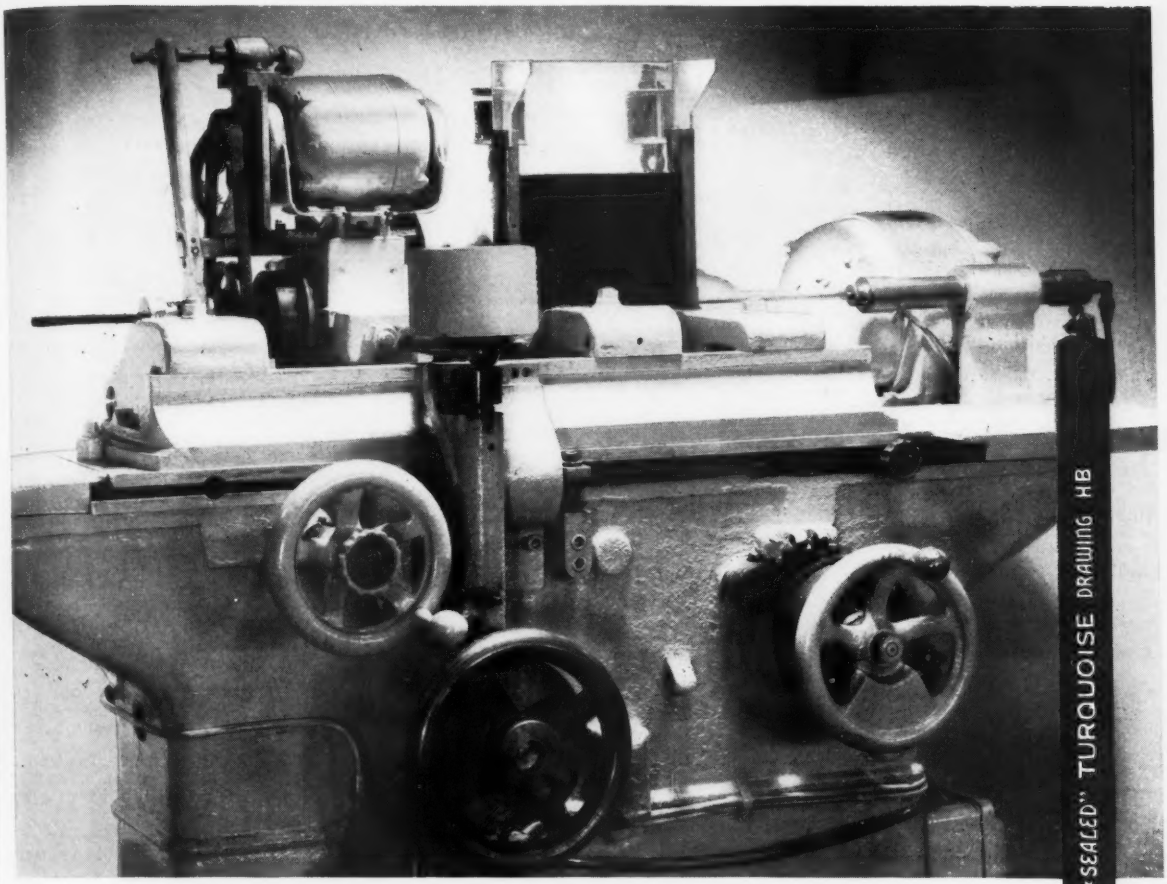


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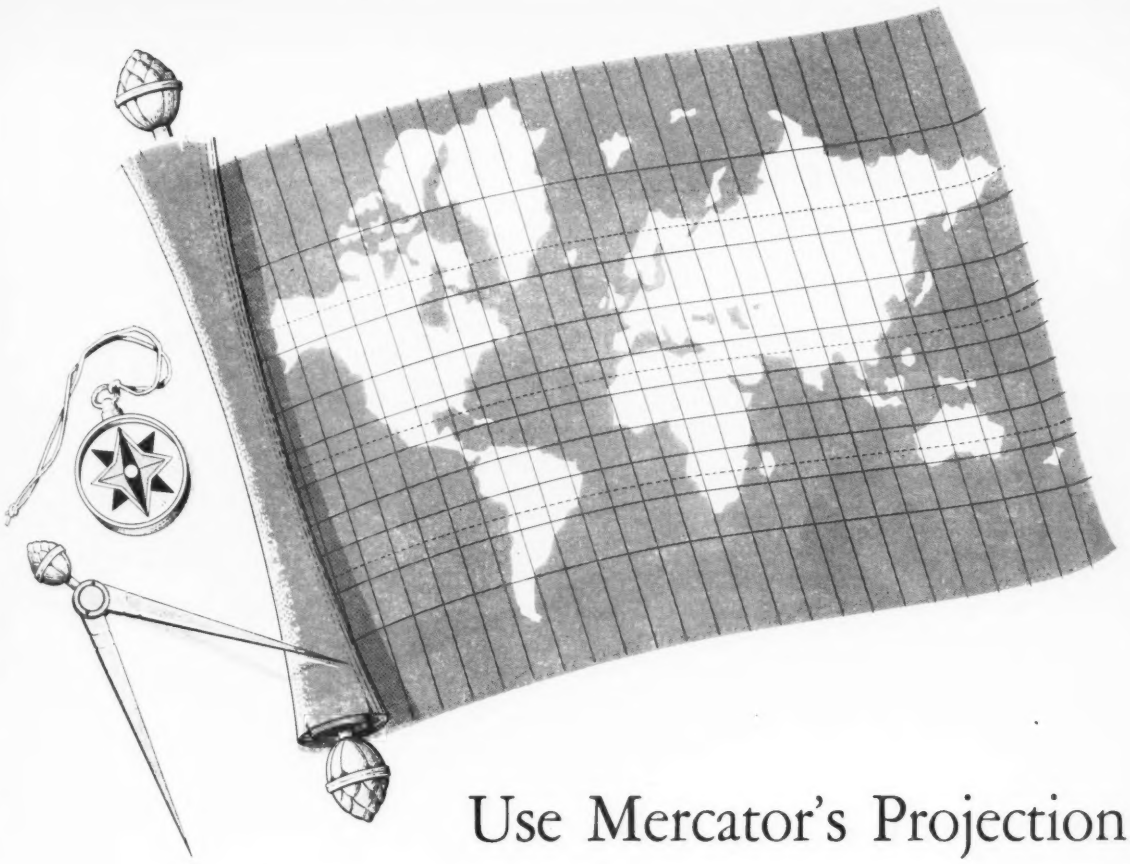

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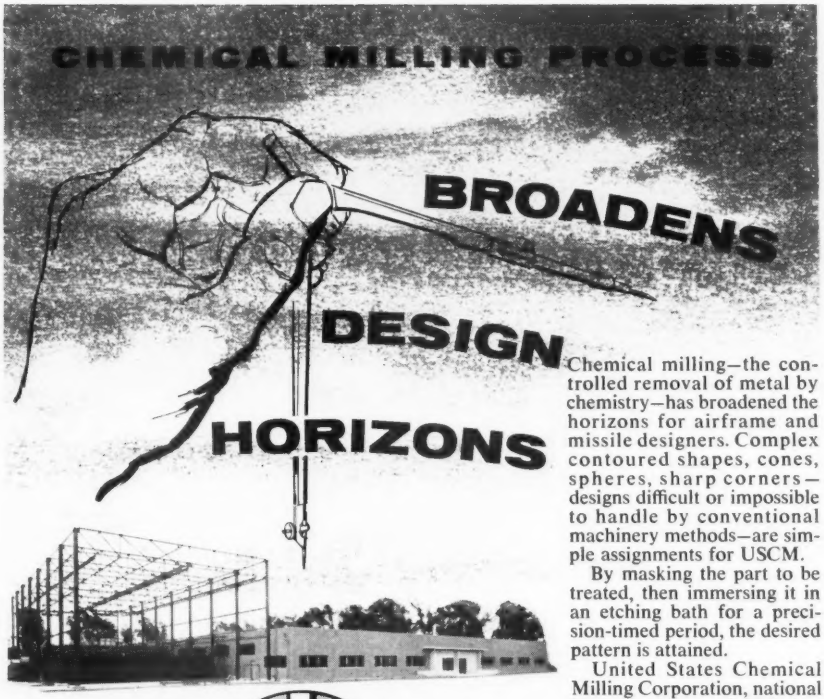


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## Dalmo Victor Company

Hahn, Stuart H., Engrg. Cons.
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## The Dalton Foundries, Inc.

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## Dana Manufacturing Co.

Adler, R. C., Owner

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## Decker Aviation Corporation

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## The de Florez Company, Inc.

de Florez, Rear Adm. Luis, Member, Bd. of Dir.
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## de Havilland Holdings Ltd.

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## De Laval Steam Turbine Company

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## Des Plaines Aeronautical Corporation

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## Design Service Company of New York

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## Designers for Industry, Inc.

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## De Vore Engineering Service

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## Dian Labs, Inc.

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## Dielectric Products Engineering Company, Inc.

Brown, Charles D., Pres.

## Diesel Engine Corporation

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## Doak Aircraft Company, Inc.

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## Dodco, Inc.

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## W. D. Dodenhoff Company, Inc.

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## Doman-Fleet Helicopters, Ltd.

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Wright, Robert A., Designer, Struct.
Young, Raymond A., Prelim. Design Engr.

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### Tulsa, Okla.

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Downs, William R., Service Mgr.
Ferguson, Charles William, Struct. Engr.
Fuller, George M., Aerodynamics Engr., Aerodynamics Design Gr. Leader
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Gilmore, Richard M., Assoc. Engr., Aerodynamics Sect.
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Jenny, Robert B., Aerodynamics Engr.
Jones, Cecil R., Designer
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Shultz, Bennie, Assoc. Engr., Strength Gr.
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Webb, Jack S., Aerodynamicist
Weir, Samuel G., Aerodynamicist

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Timoshek, Stanley, Magnesium Sales

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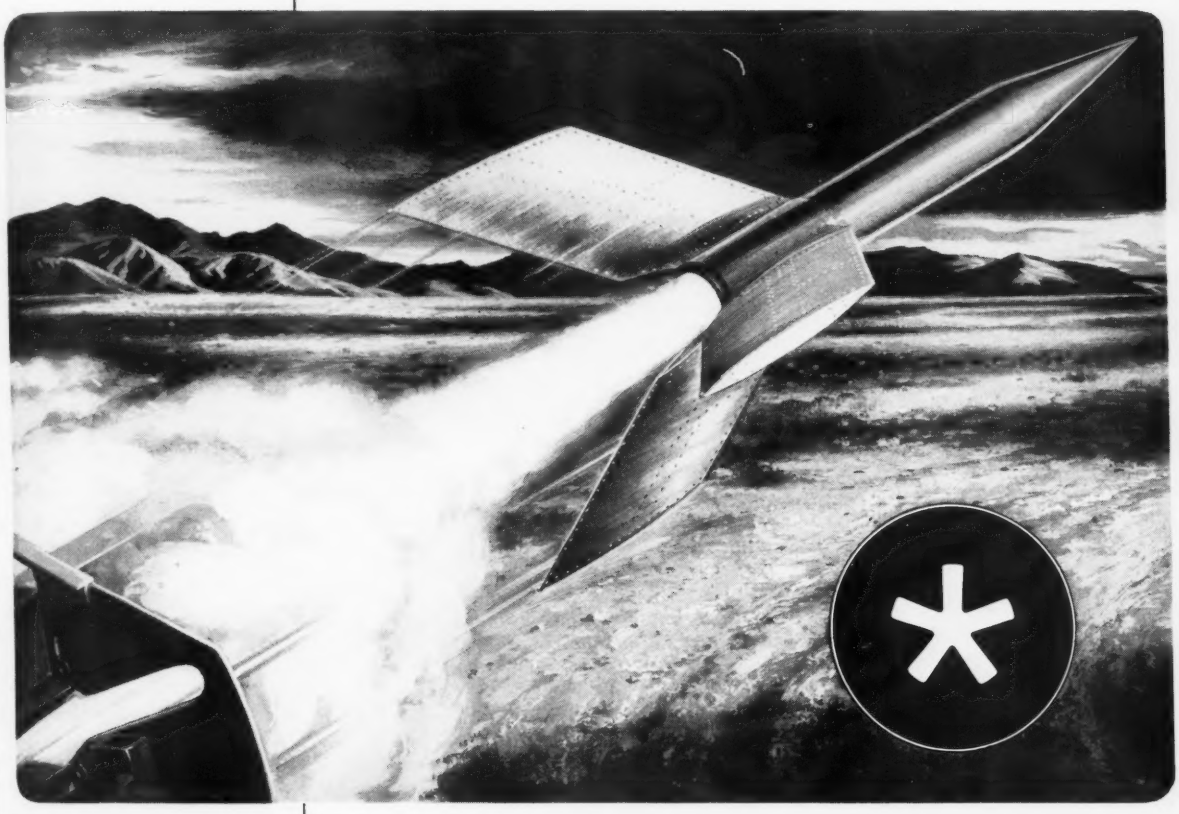

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Long, William Richard, Liaison Engr.
Lutton, L. S., Staff Asst.—Gen. Manager's Office
Lytton, Lyle, Plastics Co-ordinator
Marlow, Wayland C., Prelim. Design Engr.
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Moody, Plez P., Operations Engr. (Geographer)
Morton, Earl E., Ch.—Aerodynamics
Nagle, Omar R., Jr., Prelim. Design
Neilson, James A., Jr., Supvr. of Struct
Page, Armand J., Landing Gear Design, Liaison Engr.
Pfeiffer, R. James, Exec. Dir. of Customer Relations
Pickens, Andrew, Flight Test Engr. "A"
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Rahrig, Thomas F., Stress Tech., Prelim. Design
Rosengren, S. Norman, Design Engr.
Sellers, William H., Flutter & Vibration Technologist
Sexton, George S., Operations Engr.
Sheridan, Laurence W., Prelim. Design Engr.
Shostak, Adam, Stress Technologist
Sisson, Thomas Upton, Military Advisor
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Snodgrass, Robert R., Technologist, Aerodynamicist
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Stewart, W. Fred, Ch. Engr.
Swanger, John W., Stress Technologist
Tiffany, Raphael J., Gr. Design Engr. (Master Lines Lofting)
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Knight, Edward J., Jr., Proj. Engr., Pneumatic Controls
Lentz, George L., Proj. Engr., Production Design Proj.
McCoy, Allan W., Aerodynamics Gr. Leader
Miller, Mason F., Engrg. Specialist
Regnier, William Wayne, Devel. Engr.
Sheldon, Lewis R., Jr., Prelim. Design Engr.
Smith, William C., Engrg. Specialist

### Airsupply Company

Forisch, Edward J., Install. Engr., Landing Gear, Wheels & Brakes
Murphy, Maurice P., Installation Engr.

### Rex Division

Campbell, J. Richard, Sr. Design Engr.
Ehinger, Robert L., Personnel Mgr.

## Gaul & Voosen

Knack, Frederick J., Struct. Engr.

## William C. Geer Laboratory

Geer, William C., Owner

## Geiss Gears, Inc.

Geisse, John H., Pres.

## Genaire Ltd.

Mitchell, Keith C., Production Engr.
Picken, Harry Belfrage, Pres. & Ch. Engr.

## General Bronze Corporation

Gurney, Marshall B., Dir., Aero Div.

## General Dynamics Corporation

*Keller, Harold, Dir., Assn. Relations
Land, Vice Adm. Emory Scott, USN (Ret.), Cons.
Richardson, Rear Admiral L. B., USN (Ret.) Sr. V-P

## Canadair Limited

Adamson, Louis S., Spare Parts Sales Mgr.
Bates, D. Barker, Industrial Designer
Bernstein, Saul, Gr. Leader—Stress
Bloom, Charles A., Sect. Ch., Struct.
Bogdanoff, David, Ch. of Dynamics
Box, L., Engr.
Cavanagh, George, Lead Planner, Planning Dept.
Chow, L. H., Sect. Ch., Engrg. Exp. Sect.
Coates, Edmund W., Design Engr.
Coleman, James Cuthbert Barrington, Sect. Ch., Engrg.
Conea, M. Michael, Power Plant Engr. "A"
Cribb, Thomas George, Engrg. Technician—Engrg. Specifications & Planning
Davidson, Valentine, Gr. Leader, Engrg. Dynamics Sect.
Davies, Charles, Gr. Leader, Engrg. Dept.
Deans, Robert L., Gr. Leader, Aerodynamics
de Hart, William G., Admin. Engr.
Dietiker, Gilbert, Engr. "A"
Dishlevoy, Roy W., Engr., Prelim. Design
Dowden, Percy R., Ch., Prelim. Design Sect.
*Ebel, W. K., V-P—Engrg.
Fangor, M. W. V., A/Group Leader, Engrg. Exptl.
Greeniaus, H. J., Sect. Ch., Equipment Design
Halton, Harry, Gr. Leader, Design Engrg. Dept.
Hamelet, Jean Henry, Sales Engr.
Harvie, Thomas A., Proj. Engr.
Hayward, Ralph, Special Weapons Engrg. Design Office Supvr.
Heine, C. J., Asst. Service Mgr.
Higgins, E. H., Ch. Proj. Engr.
Irbitis, Karlis, Prelim. Designer
Kaganov, Benjamin J., Ch. Struct. Engr.
Larratt, Arthur E., Ch. of Stress
Larsson, Karl H., Ch. Sales Engr.
Lecavalier, Joseph Fernand, Flight Safety Engr.
Lilly, A. J., Mgr., Aircraft Sales
Longhurst, William S., Ch. Test Pilot
Louie, Harry, Standards Engr.
Luckert, Hans Joachim, Aerodynamics Research
Miller, Herbert H., Gr. Leader, Special Weapons Engrg.
Norsworthy, Edward, Gen. Serv. Supvr.
Notcheff, Ivan, Engr.
Phillips, Frederick C., Ch., Aerodynamics & Prelim. Design
Prust, Michael C. B., Functional Engr.
Redpath, Peter H., V-P—Sales
Rhind, Hugh, Gr. Leader—Engrg.
Saksena, Gajraj Bahadur, Design Specialist
Scales, J. Kenneth, Admin. Engr.—Devel.
Schaefer, Everett B., Asst. Ch. Engr.
Shakespeare, W. B. J., Engr. "A"
Siebes, Jos. W., Mech. Engr., Design
Sims, Arthur G., Mgr.—Sales Service
Smith, Ronald F. O., Asst. Ch. Design Engr.
Sobolewski, G. J., Gr. Leader, Engrg. Dept.
Trillo, Robert Longley, Sr. Aerodynamicist
Willis, Stanley, Draughtsman, Guided Missile Engrg.
Woodruff, Paul I., Flight Test Engr.

## Convair Division

### *Colorado Springs, Colo.*

Murray, Lester K., Mgr., Colorado Springs Office

### *Daingerfield, Tex.*

Alexander, Wayne D., Research Gr. Engr.
Arnold, J. E., Div. Mgr.
Crosby, Frank, Research Test Engr.
Eley, Herman O., Research Engr., Ord. Aerophysics Lab.
Holliday, Bobbie B., Jr. Engr.
Lobrecht, Dorr, Jr., Research Test Engr.
Luther, John M., Ch.—Jet Engine Dept., Ord Aerophysics Lab.
Smith, Dickson J., Test Engr., Ord. Aerophysics Lab.
Tate, Roger E., Wind Tunnel Test Engr.
Volluz, Raymond J., Ch., Supersonic Wind Tunnel Dept.

### *Edwards Air Force Base, Calif.*

Allwardt, Victor L., Ch. Flt. Test Gr. Engr.
Wallis, John R., Jr., Proj. Flight Test Engr.

### *Fort Worth, Tex.*

Adams, Richard E., Ch. of Prelim. Design
Addison, James L., Design Engr.
Amuedo, Arthur R., Aerodynamics Engr.
Archer, John S., Sr. Struct. Engr.
Armstrong, Forrest E., Gr. Engr., Prelim. Design
Armstrong, H. T., Staff Engr.
Armstrong, Johnny G., Aerodynamics Engr.
Ashford, Charles, III, Aerodynamics Engr.
Ball, Herbert Glenn, Aerodynamics Engr., Performance Flight Test
Ballinger, Thomas E., Aerophysics Engr.
Barnes, Kenneth Harold, Aerophysics Engr.
Benepe, David B., Sr. Aerodynamics Engr. Model Test Gr., Exptl. Aerodynamics Sect.
Bennett, Willard B., Design Engr.
Bernardi, Louis A., Aerodynamics Engr.
Besselievre, Philip H., Jr., Aerodynamics Engr.
Bishop, Joe O'Farrell, Flight Test Engr.
Boulware, Jesse M., Aerophysics Engr., Stability & Control Gr.
Bradfield, Ganey W., Sr. Design Engr.
Brickley, R. H., Gen. Rep.
Bursnall, William J., Proj. Operations Analyst
Busey, Charles H., Sr. Design Engr.
Calvit, Thomas O., Jr. Engr.
Capiaux, Raymond, Sr. Propulsion Engr.
Casteleiro, Carlos A., Aerodynamics Engr.
Christmas, Harlan F., Design Engr.
Clanton, Neil A., Proj. Aerophysics Engr.
Clemen, Arthur T., Sr. Struct. Engr.
Collinsworth, Edward Rex, Design Gr. Engr.
Cox, Ernest F., Testing Analyst
Crabtree, Charles F., Jr., Sr. Design Engr.
Craig, George Harris, Sr. Systems Installation Engr.
Cripliver, C. Roger, Engrg. Publications Editor. USAF Time Compliance Tech. Orders
Curtis, Frederick A., Jr., Aerophysics Gr. Engr.
Dansby, Ted, Sr. Aerodynamics Engr.
Darling, Ralph E., Aerodynamics Gr. Engr.
Davidson, Richard B., Struct. Engr.
Davis, Dean F., Design Engr.
Davis, Frank W., Ch. Engr.
Dewey, Gaylen L., Aerodynamics Engr.
Dietz, Wm. C., Sr. Proj. Engr.
Eckstein, Emil L., Proj. Design Engr., Prelim. Design
Erickson, B. A., Mgr.—Flight Dept.
Esenwein, August Carl, Div. Mgr.
Evans, William Leon, Gr. Engr.
Foreman, Arthur S., Propulsion Engr.
Forrest, Raymond Dale, Flight Test Engr.
Foster, George L., Jr., Sr. Design Engr.
Fox, Marvin K., Aerodynamics Engr.
Frost, Richard Carl, Proj. Aerodynamics Engr.
Frye, Robert P., Sr. Aerodynamics Engr., Exp. Aerodynamics Gr.
Funk, William F., Design Safety Engr.
Goldberg, Arthur Phillip, Struct. Engr.
Gomez, Eduardo W., Struct. Engr.
Gordon, James A., Aerodynamics Engr.
Green, Charles H., Jr., Proj. Engr.
Griffith, Billy J., Sr. Aerodynamics Engr.
Grogan, George C., Jr., Aerodynamics Gr. Engr.
Hand, William Carl, Jr., Design Engr.
Hile, Edwin E., Thermodynamic Design Gr. Engr.
Hinckley, Emmett C., Jr., Aerophysics Engr.
Hinckley, Herbert W., Asst. Ch. Engr., Proj Design
Hooks, Bentley C., Jr., Flight Test Engr.
Hopson, George D., Propulsion Engr.
Hosek, John J., Jr., Sr. Aerodynamics Engr.
Howard, Claude R., Sr. Aerophysics Engr.
Hoyler, W. F., Proj. Design Engr., Special Weapons Gr.
Hundley, Marvin Lee, Aerodynamics Engr.
Hutton, James H., Proj. Design Engr.
James, Earl E., Jr., Research Test Engr.
Johnson, Harold T., Proj. Struct. Engr.
Johnson, William S., Jr., Sr. Struct. Engr.
Kaler, George Michael, Proj. Aerodynamics Engr.
Kelbert, George O., Field Engr.
Kemp, Donald E., Sr. Struct. Engr.
Kimmons, Wylie M., Aerophysics Engr.
Krug, Edwin H., Sr. Aerophysics Engr.
Kuchar, Charles E., Proj. Aerodynamics Engr.
Kulakowski, Leo J., Proj. Aerodynamics Engr.
Ladd, Garth C., Aerophysics Engr.
Lederer, Richard W., Sr. Design Engr.
Lee, Vernon A., Aerodynamics Engr., Performance Gr., Aerodynamics
Lemmon, Robert L., Proj. Engr.
Lenderman, Donald B., Flight Test Engr.
Linn, Dudley Paul, Sr. Aerophysics Engr.
Love, Kenneth H., Sr. Design Engr.
Madsen, Alfred P., Proj. Aerodynamics Engr.
Mahaffey, Phil T., Struct. Gr. Engr.
Main, Guy F., Proj. Struct. Engr.
Mann, Charles C., Propulsion Engr.
Martin, Willis O., Aerodynamics Engr.
Marx, Howard F., Sr. Operations Analyst
Maske, Edmund B., Jr., Ch.—Aerodynamics
Masser, Paul S., Aerophysics Engr.
Mayes, Joe F., Aerodynamics Engr.
McDill, Paul L., Aerodynamics Engr., Exp. Aerodynamics Gr.
McKenzie, William T., Propulsion Engr.
Mielke, Florren W., Sr. Design Engr.
Miller, Byron D., Flight Test Engr.
Miller, Robert E., Struct. Engr.
Mitchell, Alton G., Flight Test Engr.
Munson, Lloyd E., Sr. Structures Gr. Engr.
Mutchler, John V., Proj. Aerodynamics Engr.
Nelson, Elijah Morris, Design Engr., Nuclear Proj. Design Gr.
Nevins, Clyde D., Design Engr.
Newman, Charles J., Struct. Engr.
Neyland, C. E., Aerodynamics Gr. Engr.
Nolan, James R., Sr. Design Engr., Power Plant Design Gr.
Norvell, Robert Dean, Sr. Flight Test Engr.
Oliver, Robert N., Propulsion Gr. Engr.
Ortell, Alexander R., Jr. Engr.—Aerophysics
Patton, Robert James, Sr. Aerodynamic Gr. Engr.
Peloubet, Raymond P., Sr. Struct. Engr.
Pence, Robert Forrest, Weights Design Gr. Engr.
Polk, Edwin H., Sr. Struct. Engr., Prelim. Design
Pollock, Robert T., Sr. Design Engr.
Pratt, William H., Design Engr.
Pray, Donald G., Tech. Analyst
Quint, Philip B., Struct. Engr., Loads Gr.
Reed, B. G., Asst. Div. Mgr.—Operations
Robbins, Norman B., Ch. of Proj.
Robinson, William M., Aerodynamics Engr.
Roland, Harry L., Design Weight Engr.
Saksena, Gajraj Bahadur, Sr. Aerodynamics Engr.—Aeroelasticity Gr.
Schurmann, Ernest E. H., Aerodynamics Engr.
Seacord, Charles Lynn, Jr., Sr. Aerophysics Gr. Engr.
Sierra, Celestino R., Sr. Design Engr.
Simon, William E., Aerodynamics Engr.
Slagle, Grady M., Jr., Sr. Aerophysics Engr.
Smith, Larz M., Design Specialist, Struct. Devel. Gr.
Snell, Rex L., Procurement Engr.
Stancil, Robert Thomas, Aerodynamics Engr.
Stephens, Uel, Jr., Sr. Struct. Engr.
Stewart, John D., Sr. Aerodynamics Engr.
Stucker, Harry T., Aerophysics Gr. Engr.
Studer, Vincent J., Struct. Engr.
Sullins, Robert T., Jr., Struct. Gr. Engr.
Sullivan, Thomas J., Mgr. of Contracts
Thompson, Oscar N., Proj. Struct. Engr.
Vincent, Kenneth R., Sr. Propulsion Engr.
Vrabel, Robert J., Sr. Flt. Test Engr.
Walker, Ralph McBee, Jr., Sr. Aerodynamics Engr.
Ward, Jack C., Proj. Coordinator
Watson, David B., Aerophysics Engr.
Watson, John H., Aerophysics Engr., Automatic Controls Gr.
Watson, Walter W., Jr., Design Engr.—Exp. Aerodynamics
Welton, Ralph E., Jr., Engrg. Planner
Werner, Henry J., Design Engr.
Westcott, William W., Design Safety Engr.
Wheeler, John Thomas, Aerodynamics Engr.
Whisenhant, Paul Ernest, Engrg. Illustrator
Willis, J. G., Design Specialist & Cons.
Wilson, Dan C., Proj. Design Engr.
Witchell, Arthur S., Jr., Ch. Pilot
Wolanski, Henry S., Gr. Engr., Electronic Computing Lab.

### *Pomona, Calif.*

Allardt, Clark E., Design Engr.
Bieza, Stanley M., Test Engr.
Bloom, Kenneth F., Missile Test Engr.
Bonk, Casimir J., Design Engr.
Brodsky, Robert F., Head, Aerodynamics Gr.
Burkheimer, George E., Sr. Tech. Gr. Engr.
Cucuzza, Joseph R., Hydraulics Design Engr.
Dutzi, James V., Jr. Engr.
Evans, Robert Bryce, Missile Test Analyst
Glynn, William James, Jr. Weights Engr.
Gueldner, Louis O., Jr., Design Specialist
Heller, Edward D., Sr. Design Gr. Engr.
Heyman, Donald F., Struct. Engr.
Jackman, Kenneth R., Ch. Engr., Test Labs., Guided Missile Div.
Jackson, Paul H., Jr., Sr. Aerodynamics Engr.
Jacobson, Orlin Milton, Missile Test Engr.
Jowitt, James L., Dynamic Engr.
Landberg, Stanley H., Aerodynamist
Loomis, Robert C., Asst. Div. Mgr.—Operations
Marcinek, Jack J., Sr. Thermodynamics Engr.
Maxwell, Norman E., Sr. Aerodynamics Engr.
McIntosh, William A., Sr. Thermodynamics Engr.
McMaster, Alexander, Staff Engr.
Miller, Percy H., Sr. Aerodynamics Engr.
Palmer, A. E., Engrg. Gen. Supvr.
Rugge, George F., Jr., Missile Test Engr.
Saville, Eric J., Design Gr. Engr.
Stevenson, R. E., Design Specialist
Stoughton, Milton F., Sr. Staff Engr., Proj. Asst. for Design Coordination
Swetnam, Robert L., Design Engr.
Teague, Mrs. Pauline V., Research Engr.
Verlangieri, Vincent C., Engr.—Flight Analyst
Vogel, Theodore A., Tech. Gr. Engr.
Whitehill, William V., Sr. Dynamics Engr.

### *San Antonio, Tex.*

Clegern, William A., San Antonio Mgr.

### *San Diego, Calif.*

Abels, Alan W., Asst. Dir., Commercial Sales
Adamson, James M., Design Specialist
Alley, D. J., Sr. Dynamics Engr.

Allwardt, Victor L., Ch. Flight Test Gr. Engr.
Alter, Horace J., Sr. Design Engr., Prelim. Design
Amster, Warren, Research Engr., Operations Analysis Gr.
Anderson, Lawrence C., Flight Test Engr.
Andreasson, Bjorn O., Sr. Design Engr., Leadman, Controls Gr.
Andrew, Lowell V., Sr. Dynamics Engr.
Applegate, F. Daniel, Sr. Design Gr. Engr. Propulsion & Air Conditioning
Armstrong, Gene L., Design Specialist
Avgerenos, Alexander, Sr. Design Engr.
Ballentine, Don C., Research Analyst, Experimental Flight Engrg.
Ballou, L. Farwell, Jr., Aircraft Power Plant Install. Design Engr.
Batten, Robert L., Test Engr.
Bauer, Robert L., Struct. Engr.
Baxter, Richard D., Sr. Flt. Test Engr.
Bayless, Ralph L., Ch. Engr.
Bender, Ray W., Thermodynamics Engr.
Bennett, Dwight H., Ch. of Aerodynamics
Biering, Albert H., Flight Test Engr.
Blake, Charles L., Staff Engr., Office of the V-P—Engrg.
Blumberg, Sam E., Sr. Flight Test Engr.
Blumer, Charles B., Aerodynamics Engr.
Bova, Joseph A., Sr., Design Engr.
Bowyer, James M., Jr., Sr. Thermodynamics Engr.
Breitenbach, Max "J," Sr. Struct. Engr.
Brooke, H. E., Ch. of Hydrodynamics
Brooks, H. T., Engrg. Admin. Supvr.
Brown, Leon D., Jr., Flight Test Engr.
Bruski, Edmund, Design Engr.
Bulinski, Ronald J., Aerodynamics Engr.
Burstein, Adolph, Asst. Ch. Engr.—R&D
Byrne, John T., Hydrodynamics Engr.
Carter, Wilbert V., Asst. Gr. Engr.
Castle, Richard Peter, Design Engr.—Armament
Chalk, Joseph B., Design Engr., Prelim. Design Gr.
Chausse, Ronald H., Gr. Engr., Flight Test Analysis Gr.
Cheney, Harold K., Ch. Flight Test Engr.
Cheung, Lam Tai, Sr. Struct. Engr.
Christensen, Grant D., Asst. to V-P—Engrg.
Cihak, Richard W., Jr. Engr.
Clause, Melvin, Field Service Engr.
Clements, L. V., Design Specialist
Close, R. A., Design Engr.
Coddou, Joseph W., Sr. Design Engr.
Croome, Harry, Test Engr., Engrg. Test Lab.
Crupi, Raymond F., Design Engr.
Culbertson, Philip E., Design Specialist—Aerodynamics
Cumming, David P., Aerodynamics Engr.
D'Annunzio, Mario G., Aerodynamic Engr.
DeBevoise, John Manley, Sr. Aerodynamics Engr.
Dickard, Herbert E., Sr. Design Engr.
Dickey, Paul I., Aerodynamic Engr.
Diller, Donald E., Sr. Struct. Engr.
Donaldson, John D., Asst. Mgr., Commercial Sales
Dore, Frank J., Staff Asst., Engrg.
Dorrance, William H., Asst. to the Dir. of Scientific Research
Droege, Wm. C., Gr. Engr., Engrg. Flight Test
Duffey, Lilah W., Procedures (Proofing & Mockup)
Dvorak, Harry W., Sr. Design Engr.
Eckert, Hans U., Sr. Aerodynamics Engr.
Edelstein, Murray I., Flight Test Engr.
Ehricke, Krafft A., Gr. Engr., Pre-Design & Systems Analysis–Model 7
Eilert, Morgan B., Jr., Design Engr.
Ellis, J. Dean, Sr. Design Specialist
Erickson, Carl G., Test Engr. "A"
Ewert, Edward C., Sr. Struct. Engr.
Famme, Joseph H., Asst. Ch. Engr.
Fox, William W., Proj. Engr.
Freelin, J. Raymond, Struct. Engr.
Frick, Charles William, Ch. of Applied Research
Friedrich, Hans R., Ch. Flight Mechanics Engr.
Gallagher, Robert E., Flight Test Engr.
Gammal, Abraham A., Sr. Aerodynamics Engr.
Germeraad, Donald P., Ch. Engrg. Test Pilot
Geudtner, Walter J., Jr., Sr. Aerodynamics Engr.
Glasson, Clyde L., Designer, Powerplant Gp.
Goodrich, Robert B., Design Engr. Propulsion Gr.
Gossett, Wm. M., Specification Analyst
Greene, Francis P., Sr. Thermodynamics Engr.
Greer, Dick L., Struct. Engr.
Greiner, Herbert, Aero. Engr.
Griffith, John S., Sr. Thermodynamics Engr.
Gunthorp, Seth, Design Specialist
Haas, S. G. Frank, Jr., Ch. Devel. Engr.
Hayes, Robert Byron, Design Engr.
Hendershot, Kenneth C., Thermodynamics Engr.
Herreshoff, J. B., Design Specialist
Hester, Wayne C., Engr., Exp. Flight Test
Holt, Robert L., Dynamics Engr.
Hopkins, John W., Sr. Design Engr., Prelim. Design Dept.
Kahler, Frederick A., III, Aerodynamicist
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Keller, W. C., Mgr., Customer Relations Dept.
Kelly, Charles P., Jr., Dynamics Engr.
Kennedy, Ernest D., Sr. Research Engr.
Kourbelas, N. S., Sr. Struct. Engr.
Kuhns, Robert M., Sr. Flight Test Engr.
Latimer, Merrill Dale, Test Engr., Engrg. Test Labs.
Laudeman, Ernest C., Flight Test Engr.
Lester, Wm. A., Sr. Design Engr.
LeVine, J. W., Sr. Struct. Engr.
Lindgren, Edwin E., Design Engr.
Lorenz, George C., Thermodynamics Engr.
Love, Charles Carleton, Jr., Sr. Thermodynamics Engr.
Lynch, Robert A., Sr. Design Engr.
MacCarthy, Walter T., Wind Tunnel Mgr.
MacLellan, Andrew D., Sr. Dynamics Engr.
Magoski, Peter, Design Engr.
Majcan, Walter M., Flight Test Engr.
Mancuso, Dewey J., Dynamics Engr.
Martin, Richard E., Dynamics Engr.
Masaki, Mamoru, Design Specialist
Mason, Jack, Staff Engr. to V-P—Engrg.
Matteson, Harry C., Aerodynamics Gr. Engr.
McKinney, Wilbur T., Sr. Dynamics Engr.
McLarin, Maitland, Flight Test Engr. (Telemetering), Flight Test Operations Dept., Exp. Flight
Meissner, Claus J., Struct. Engr.
Melanson, J. Lloyd, Procurement Follow-Up
Miller, Kenneth R., Sr. Design Engr., Elec. & Electronics Gr.
Miller, Roy A., Struct. Design Specialist
Milliken, Samuel Allen, Sr. Dynamics Engr., Aircraft Stability & Control
Minor, C. Dwight, Design Engr.
Mollering, William H., Customer Requirements Engr. (Navy)
Moore, Robert E., Flight Test Engr.
Morgan, Arthur David, Jr., Struct. Engr.
Morgan, Harold V., Dynamics Flight Test Analyst
Moroney, James E., Sr. Flight Test Engr.
Mothersole, George F., Aerodynamics Engr.
Murray, Lester K., Asst. to V-P—Plans
Nakamura, Hideyoshi, Design Specialist
Nilsen, Roy T., Sr. Design Engr.
Norse, John, Design Engr.
Nugent, Wilfred, Sr. Design Engr.—Gen. Design
O'Hare, George W., F-102 Proj. Mgr., Holloman AFB, N.M.
Ostenso, Donald T., Sr. Design Engr.
Otis, David R., Thermodynamics Engr.
Pasternack, Joseph M., Head—Operational Analysis
Payne, Louis A., Dynamics Gr. Engr.
Pennoyer, Vice Admiral Frederick W., Jr., USN (Ret.), Research Engr.
Perkins, Frank M., Prelim. Design Engr.
Pesek, Wilbert G., Sr. Design Engr. (Checking Dwgs. & Design Group)
Phillippi, Ralph L., Design Gr. Engr.
Pincus, Leonard C., Thermodynamics Engr.
Piper, James E., Sr. Dynamics Engr.
Plummer, Chas. P., Design Engr., Wind Tunnel Dept.
Pucci, Paul F., Sr. Thermodynamics Engr.
Ramsey, Joseph C., Aerodynamics Engr.
Ray, William A., Design Engr.
Reeder, Walter D., Sr. Aerodynamics Engr.
Rice, Robert C., Sr. Flight Test Engr.
Riedler, A. D., Design Specialist
Ritter, Arnold P., Aerodynamicist
Robinson, Harold Lester, Sr. Aerodynamics Engr.
Robinson, Richard S., Engrg. Writer, Engrg. Service Publications
Romig, Mary F., Research Scientist, Scientific Research Gr.
Rosenbaum, Mortimer, Asst. Ch. Engr.
Rother, Carl J., Research Gr. Engr.
Schaefer, W. H., Sr. Struct. Engr.
Schnaubelt, Franz Joseph, Design Engr.—Hydrodynamics
Seaton, Charles Herbert, Sr. Aerodynamics Engr.
Sebold, Raymond C., V-P—Engrg.
Service, William E., Design Engr., Fuselage Design Gr.
Shard, Ralph F., Design Engr.
Sherar, Dewey A., Sr. Flight Test Engr.
Shue, George L., Design Specialist
Sinclair, Frank D., Dir. of Foreign Sales, Commercial Sales Dept.
Skoog, Edward W., Struct. Engr.
Smith, Dickson J., Thermodynamics Engr.
Starr, Sterling V., Aerodynamics Engr.
Streed, Rodney W., Sr. Dynamics Engr.
Struthers, John H., Sr. Aerodynamics Engr.
Tafe, Harvey C., Military Relations Dir.
Tanalski, Theo. T., Sr. Struct. Engr.
Tearnen, John O., Sr. Thermodynamics Engr.
Thomas, D. M., Sr. Aerodynamics Engr.
Tomascheski, J. F., Flight Test Engr.
Tripp, Fay L., Struct. Engr.
Tunstall, Reginald Vaughan, Flight Test Engr.
Van Norman, Allen, Struct. Engr.
Waldo, Richard K., Market Research Mgr.
Wallis, John R., Jr., Flight Test Engr.
Ward, Kenneth E., Aerodynamicist
Weissman, Jerome, Flight Test Engr.
Wen, William L., Dynamics Engr.
Wendt, Harold O., Pre-Design Engr.
Wener, N. Leonard, Sr. Dynamics Engr.
Wennhold, William F., Design Engr.
Wenzel, James G., Sr. Aerodynamics Engr.
Werner, Norbert M., Aerodynamics Engr.
Westbrook, R. C., Sr. Struct. Engr.
Whigham, Eugene E., Sr. Flight Test Engr.
White, Edmund F., Aerodynamics Engr.
White, Richard P., Proj. Engr.
Wiemann, Albert B., Jr., Aerodynamics Engr.
Williams, Arthur L., Sr. Struct. Engr.
Willis, J. G., Design Specialist
Wilson, John Calvin, Jr. Engr.
Withee, W. W., Asst. Ch., Engrg. Flight Test
Woersching, Thomas B., Design Specialist in Operations Analysis
Wokuluk, John John, Design Engr.
Worden, Donald C., Proj. Engr.
Wozniak, Frank B., Design Specialist
Wright, Robert M., Flight Test Engr.

### Electric Boat Division

McPherson, John B., Ch., Ind. Sales
Sheets, H. E., Ch. Research & Devel. Engr.
Vieweg, Rear Adm. W. V. R., USN (Ret.), Asst. Ch., R&D Engr.

### Stromberg-Carlson Division

Surwillo, Phillis L., Designer, Electronics Engrg. Dept.

## General Electric Company

### Dayton, Ohio

Elcan, William C., Mgr., Elec. Equip., Aviation & Defense Industries Sales
Jamison, David F., Sales Engr.—Aviation & Defense Ind. Sales
McTigue, George J., Mgr.—Aircraft Engine Sales, Central District
Olberding, Vincent P., Mgr., Sales, Aircraft Systems
Stanger, Walter E., Aviation Specialist
Stelzner, W. B., Jr., Dist. Specialist

### Edwards Air Force Base, Calif.

Jackson, Harry B., Proj. Engr., F-101 Flight Test
Miller, Frank Faust, Data Calculator
Smith, Richard B., Supvr., Flight Test Engrg.
Weaver, Virgil L., Mgr., Pilot Test

### Evendale, Ohio

Addison, Glenn T., Aircraft Systems Evaluation, New Product Planning
Albert, Edward Vernon, Mgr., Product Planning & Marketing Research, JED
Anderson, Harry B., Tech. Engr. (Design) AGT Div.
Arms, Richard P., Mgr., Mech. Devel. Sub-Sect., JED
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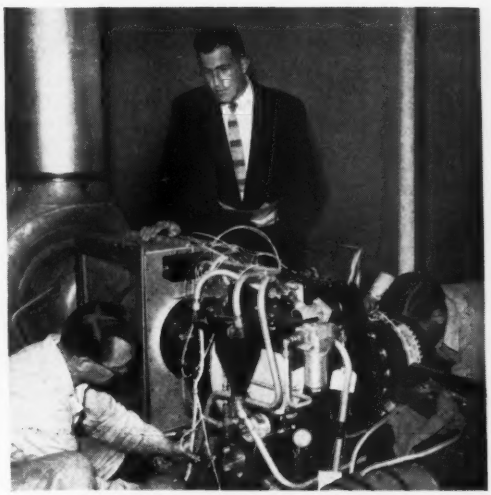

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Bearden, Bruce M., Designer
Brewer, Roger P., Sr. Engr., Plant Engrg. Dept.
Burbick, James Warren, Stress Engr.
Caluya, Flor N., Stress Analyst
Christ, Paul John, Jr., Engrg. Illustrator
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Comer, F. D., Struct. Designer
Couts, R. J., Head, Gen. Design—Aerophysics Depts.
Cox, William Ralston, Stress Analyst
Curl, Arthur N., Engrg. Specialist—Power Plant Inst. Design
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Probst, Joseph
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Ramsden, Earl I., Proj. Engr.
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Rogers, Alden L., Aerodynamicist
Rogers, Samuel B., Prelim. Design Engr.
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Rowley, Frederick C., Engrg. Test Pilot
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Schaffer, Arnold Philip, Struct. Flight Test Engr.
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Spaulding, Howard O., Power Plant Install. Engr.
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Spruill, Cecil E., Struct. Liaison Engr.
Sutton, W. L., Production Mgr.
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Trott, Warren Calvin, Aerodynamicist—Stab. & Control
Tsirimokos, John X., Research Engr.
Tsongas, Alexander, Struct. Proj. Engr.
Ulrich, Karl Walter, Aerodynamicist—Stability & Control
Umstetter, John J., Struct. Flight Test Engr.
Valdivia, Francis S., Struct. Engr. (Stress Analysis)
Van Name, John F., Design Engr.—Control Surfaces
Varisco, Angelo, Design Engr.
Varvaro, Anthony, Design Training Engr.
Villalba, Ivan, Stress Analyst
Visconti, Joseph, Struct. Engr.
Wade, Wm. Eugene, Jr., Asst. Ch., Aerodynamics
Wagner, Hart, Flight Test Engr.
Walsh, Joseph G., Aerodynamicist
Watts, Linden L., Jr., Model Design Engr.—Aerodynamics
Wehle, L. Brandeis, Jr., Ch., Struct. Methods Gr.
Weiss, Leonard J., Struct. Engr.
Wendell, Kenneth F., Install. Engr.
Wennagel, Glen J., Struct. Proj. Engr.
Whitaker, Arnold B., Head, Dynamic Controls Gr.
White, Robert F., Engr.
Whitson, Charles A., Liaison Struct. Engr.
Wittko, Joseph N., Power Plant Install. Engr.
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Yorke, Duane, Stability & Control Aerodynamicist
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Zoudlik, Rudolph J., Controls Engr.
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Budiansky, Bernard, Assoc. Prof. of Struct. Mech.
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Frassinelli, Guido J., Student, Grad. School of Business Admin.
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Messinger, Carl W., Jr., Proj. Engr.
Meyer, Harold J., Test Engr.
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Bajkowski, Frank Walter, Sr. Design Engr.
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Blackburn, Albert W., Engrg. Test Pilot
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Carlton, Lindley A., Engr.—Struct.
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Weiner, Frederick, Sr. Design Engr.
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Garton, Wendell P., Engrg. Pilot
Haight, Bruce R., Supvr., Field Test Operations
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## North American Instruments, Inc.

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## North American Supply, Inc.

Hutchinson, B. W. B., V-P

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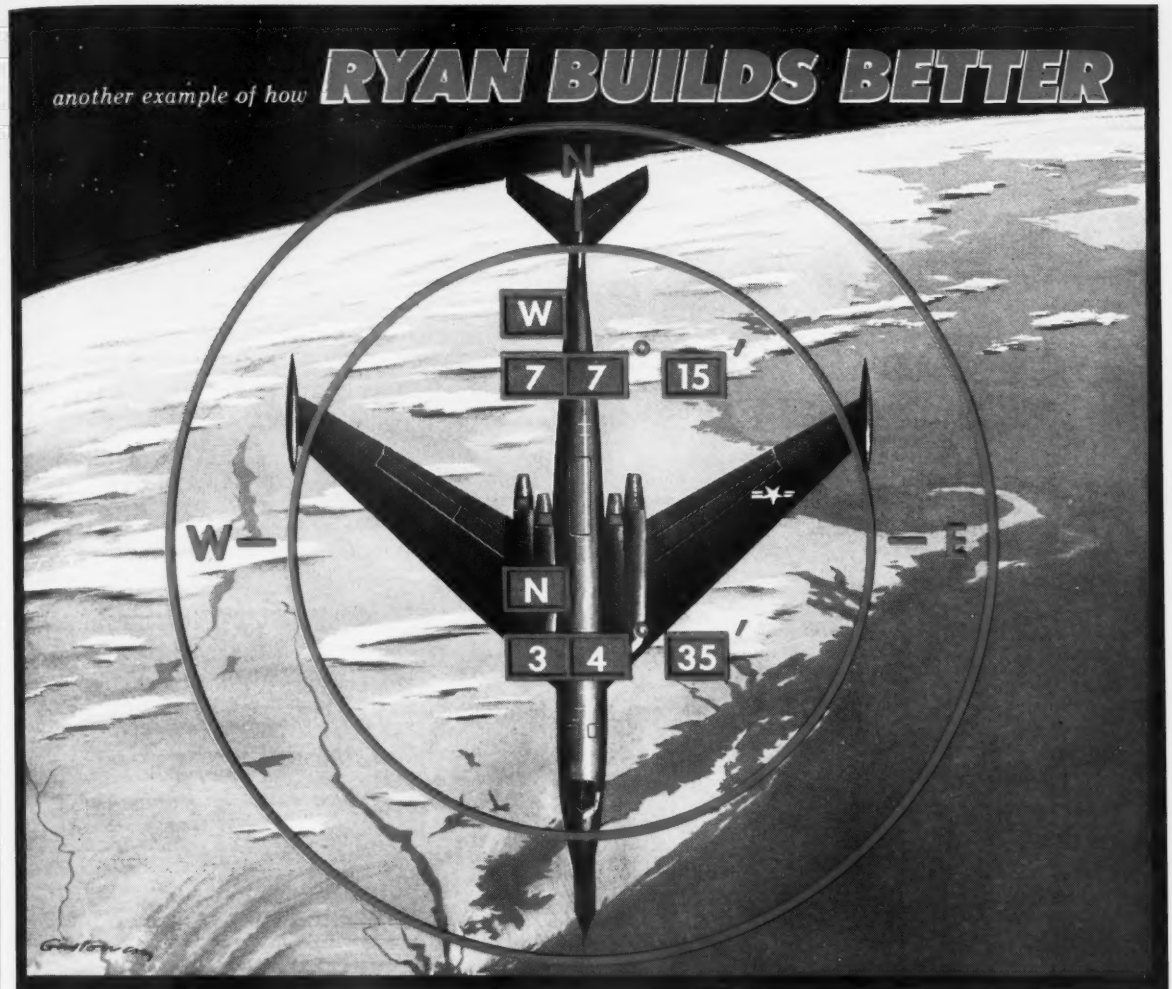


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Brownback, Henry Lowe, Tech. Counsel

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Newkirk, Burt Leroy, Prof. Emeritus
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## Repair & Sales Depot, Inc.

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Argiriou, Demetrius, Designer
Arrow, Bernard, Principal Dynamicist—Flutter Model Design & Testing
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Beck, Edgar B., Design Safety Analyst
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Bergey, Milton C., Design Engr.
Bergh, Roland C., Ch. Staff Engr.
Berkow, Murray, Dir., Sales Engrg.
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Black, Archibald, Engr.—Report Writer
Blauvelt, Robert M., Material Review Engr.
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Colaluca, Carmine John, Jr., Sr. Research Engr.
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Gould, Leslie D., Procurement Inspector
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Grossman, Norman, Systems Engr.—Flight & Fire Control
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Matarazzo, Aniello, Aerodynamicist
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*Peale, Mundy I., Pres.
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Stieglitz, William I., Design Safety Engr.
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Telles, Sanford, Sr. Struct. Engr.
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Voboril, Robert C., Production Design Engr.
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Zadikov, Victor M., Principal Research Engr.
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Fullam, Richard J., Principal Flight Test Engr.
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Mirman, Jean, Stress Analyst
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Voutsas, Alexander M., Principal Aerodynamicist

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Voboril, Robert C., Quality Control Rep., Switzerland

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Burnett, Howard R., Aerodynamics Engr.
Carroll, Patrick C., Aerodynamicist
Cockburn, John, Engrg. Design
Cordas, A. C., Supvr.—Material Review
Coward, Ken S., Prelim. Design Engr.
Danch, Gabriel C., Wash. Rep.
Davis, Walter B., Jr. Engr.
Deyarmond, Albert B., Ch., Prelim. Design, Engrg. Div.
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Elliott, Roger D., Design Engr.
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Fuhrman, Robert A., Ch., Tech. Sect.
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Harper, David C., Engr., Fuselage Design Gr.
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Martin, H. S., Exec. Asst.
Mason, James S., Jr. Engr.
Mitchell, Bruce, Ch. of Struct.
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Rasey, J. Allen, Dynamicist
Roberts, Edward E., Schedules Engr.
Row, Perry V., Designer "B"
Ryan, T. Claude, Pres.
Schult, Wilhelm F., Aerodynamics
Schwab, George H., Asst. to Mgr.—Methods Engrg.
Schwanhausser, Robert R., Rep.
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Sly, Edward D., Ch. Test Proj. Engr.
Springer, Robert E., Devel. Planning Engr.
Tuttle, Donald T., Proj. Engr.
*Wagner, William, Dir. Public & Employee Relations
Weideman, Walter H., Jr., Aerodynamicist
Wieveg, Raymond E., Research Lab. Analyst, Power Plant Gr.
Wong, Ivan L. L., Assoc. Engr.
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Brising, Lars H., V-P—Engrg.
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Küntzel, Klas O., Systems Design Engr.
Lakomaa, Arne A. G., Proj. Engr.
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Ljungström, Olle, Proj. Engr.
Lofkvist, Hans-Eric, Ch. Engr.
Norén, Gunnar, Servo Systems Research Engr.
Palme, Hans Olof, Head, Systems Engrg. Dept.
Roed, Aage E.
Roos, E. G. Tage, Aero. Research Scientist
Schalin, Peter H. B., Head, Guided Missiles Gr.
Turner, Fred H., Ch. of Stress Office
Wänström, Frid, Ch. of Research

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Pepper, William B., Staff Member
Pope, Alan, Supvr., Exp. Aerodynamics Div.
Reed, James F., Staff Member, Aerodynamicist
Vaughn, Harold R., Aerodynamicist

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Price, Wesley, Assoc. Editor

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*Speas, R. Dixon, Aviation Cons.

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McKenney, Henry F., Ch. Engr.
van Gelder, Cornelius A., Liaison Engr.
Weber, William F., Mgr., Army Contracts

#### Sperry Farragut Company

Meade, Carl B., Sect. Foreman Tech.

#### Sperry Gyroscope Company

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Athen, Adolph John, Proj. Engr.
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Benneck, Conbert Hans, Field Engr.
Berler, Irving, Engrg. Sect. Head—Special Projects
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Brannin, Richard S., Dir., Research & Advanced Devel., Aero. Equip. Div.
Brooks, William N., Jr., Sr. Engr., Flight Instrument Dept.
Brown, Gerald D., Sect. Head for Maint., Flight Research Dept.
Brown, Ralph W., Public Info. Rep.
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Clement, Warren F., Engr., Advanced Devel., Aero. Equip. Div.
Conace, Frank, Sales Mgr., Aero. Equip. Div.
Darsey, George E., Sales Rep.
Davis, Robert A., Sr. Engr.
Deutsch, Richard A., Engr.
Evans, George Dorsey, Engrg. Sect. Head
Falkenstrom, Edward, Field Engrg. Supvr.
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Fourney, David R., Sales Engr.
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Ganz, Leonard S., Engr.
Geller, Edward S., Assoc. Engr.
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Greer, Ralph T., Asst. District Mgr., Southwestern District Office
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Harry, Paul L., Supt.—Field Serv., Repair Dept.
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Heydon, Douglas Allyn, Engr., Missile Weapons System Dept.
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*Holschuh, Carl G., Exec. V-P & Gen. Mgr.
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Kleinman, Joseph M., Tech. Writing Supvr., Aero. Equip. Div.
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Koeppel, Samuel S., Publications Engr., Aero. Equip. Div.
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Lazar, Edward F., Dir., Federal Dept.

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McAtee, William C., Field Engr.
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Seels, Henry Frank, Field Serv. Engrg. Supt.
Shapiro, Henry L., Systems Engr.
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Sparling, Eric C., Secy. & Asst. to Gen. Mgr.
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Steuer, Richard G., Proj. Engr., Flight Control Dept.
Story, Philip C., Sr., Engrg. Sect. Head—Guidance Systems Dept.
Strihafka, Louis F., Proj. Engr.
Swisher, Leon N., NW Dist. Mgr., Seattle, Wash.
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Warren, Henry W., Rep., Air Systems Dept.
Webel, Lewis, Aero. Sales Engr.
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Hutchison, Dale H., Asst. to Dir., Physical Sciences Div.
Low, Lawrence J., Sr. Research Engr.

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Flügge-Lotz, Irmgard, Lecturer in Mech. Engrg.
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Kline, Stephen J., Asst. Prof. of Mech. Engr.
Nanevicz, Stanley J., Grad. Student
Niles, Alfred S., Prof. of Aero. Engrg.
Reid, Elliott G., Prof. of Aerodynamics, Guggenheim Aero. Lab.
Schwartzman, Lenwood Kent, Student
Timoshenko, S., Prof.

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Price, R. Allen, V-P, Sales & Service
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Korvin-Kroukovsky, Boris V., Research Prof., Exp. Towing Tank
Murray, Allan B., Asst. Dir.—Exp. Towing Tank
Odenbrett, Clayton L., Asst. Research Engr., Exp. Towing Tank
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Marschner, Walter K., Gr. Engr., Liaison Engrg.
McDavit, John W., Jr., Sr. Tool Planning Engr.
Moszer, Sidney, Stress Engr.
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Seredinsky, Vladimir, Engr.—Gr. Leader
Stowe, Lewis J., Asst. Ch. Engr.
*Stroukoff, Michael, Pres., Ch. Engr.

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## Sumitomo Metal Industries, Ltd.

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Ruffin, M. B., V-P—Sales

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Cady, Joseph George, Instr. in Aero. Engrg.
Eskinazi, Salamon, Assoc. Prof.—Mech. Engrg. Dept.
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Muftuoglu, Osman Saffet, Research Asst.

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Baylor, Robert N., Stress Analyst "A"
Boyd, Donald S., Engr.
Brooks, Doyle T., Jr., Ch. of Struct.
Clark, William S., Admin. Engr.
Crook, Norman L., Ch. Aerodynamicist
Edholm, Robert M., Ch., Military Liaison
Evans, J. Gary, Jr., Proj. Engr.
Grisham, N. D., Methods Devel. Gr. Engr.
Hawkins, W. Kent, Thermodynamics Gr. Engr.
Hearn, D. L., Ch. Engr.
Hubbard, Joel R., Designer "B," Power Plant Gr.
Jensen, Soren C., Jr., Aerodynamicist
Johnson, Richard H., Aerodynamics Engr.
Lowe, Harold W., Gr. Engr., Flight Test
Marx, Howard F., Design Specialist—Operations Research
Miller, Ralph S., Struct. Engr.
Morrison, F. Robert, Flight Test Engr.
Mueller, Merle C., Ch. Engr., Garland Div.
Murtaugh, Clyde R., Aerodynamics Engr.
Palley, I. Nevin, V-P—Energ.
Reynolds, Joe D., Design Engr.
Ridenour, P. J., Jr., Supvr.—Systems Design
Ross, Wm. M., Jr., Methods Analysis
Sawyer, John M., Design Engr., Wing Gr.
Spaulding, Gene B., Tech. Dir.
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Warynick, Edward W., Supvr.—Flight Test Analysis & Operations

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Gregory, John R., Mgr., Aircraft Div.
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Heller, Jack A., Sr. Devel. Engr., Accessories Div.
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Koffel, John K., Product Engrg. Mgr., Accessories Div.
Kresse, Arthur O., Proj. Engr.
McKinnon, Roy A., Devel. Engr., Jet Div.
Oppenheimer, Frank L., Engrg. Specialist
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Spangler, Selden Booth, Jr., Devel. Engr.
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Thomson, Arthur R., Proj. Engr., Compressors, Air Turbine Motors & Auxiliary Power Units
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*Collings, John A., Exec. V-P
Conner, Charles H., Flight Supt.
Crow, Lofton D., Pilot
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Evans, J. R., Supvr.—Flight Engrs., Western Region
Fannon, Marcy B., Supvr., Aircraft Economic Analysis
Hartline, David A., Engr.
Hartiine. Paul A., Proj. Engr.
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Lewis, Evan, Airline Pilot & Capt.
Mrencso, Theodore W., Airline Flight Engr.
Phelan, Dennis Joseph, Supvr., Engrg. Aerodynamics
Rummel, R. W., V-P—Engrg.
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Comstock, Kirke W., Jr., Engr.
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Eber, Lloyd W., Engr. "B"
Ernst, Edward A., Flight Officer
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Hubbard, Herbert B., Staff Supt.—Applied Math.
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Kelso, Lester G., Devel. Engr.
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Larson, O. T., Gen. Mgr., Ground Services
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McIver, Robert M., Engrg. Test Pilot
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Norheim, Torleif, Aircraft Engr.
Overton, John, Aircraft Engr.
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Beggs, John C., Designer
Boyajian, Ara Martin, Devel. Engr.
Civiello, Daniel P., Field Serv. Rep.
Dernbach, Anthony F., Devel. Engr.
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Huxley, William P., Sales Mgr.
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Woodruff, Edward C., Jr., Design Layout Draftsman

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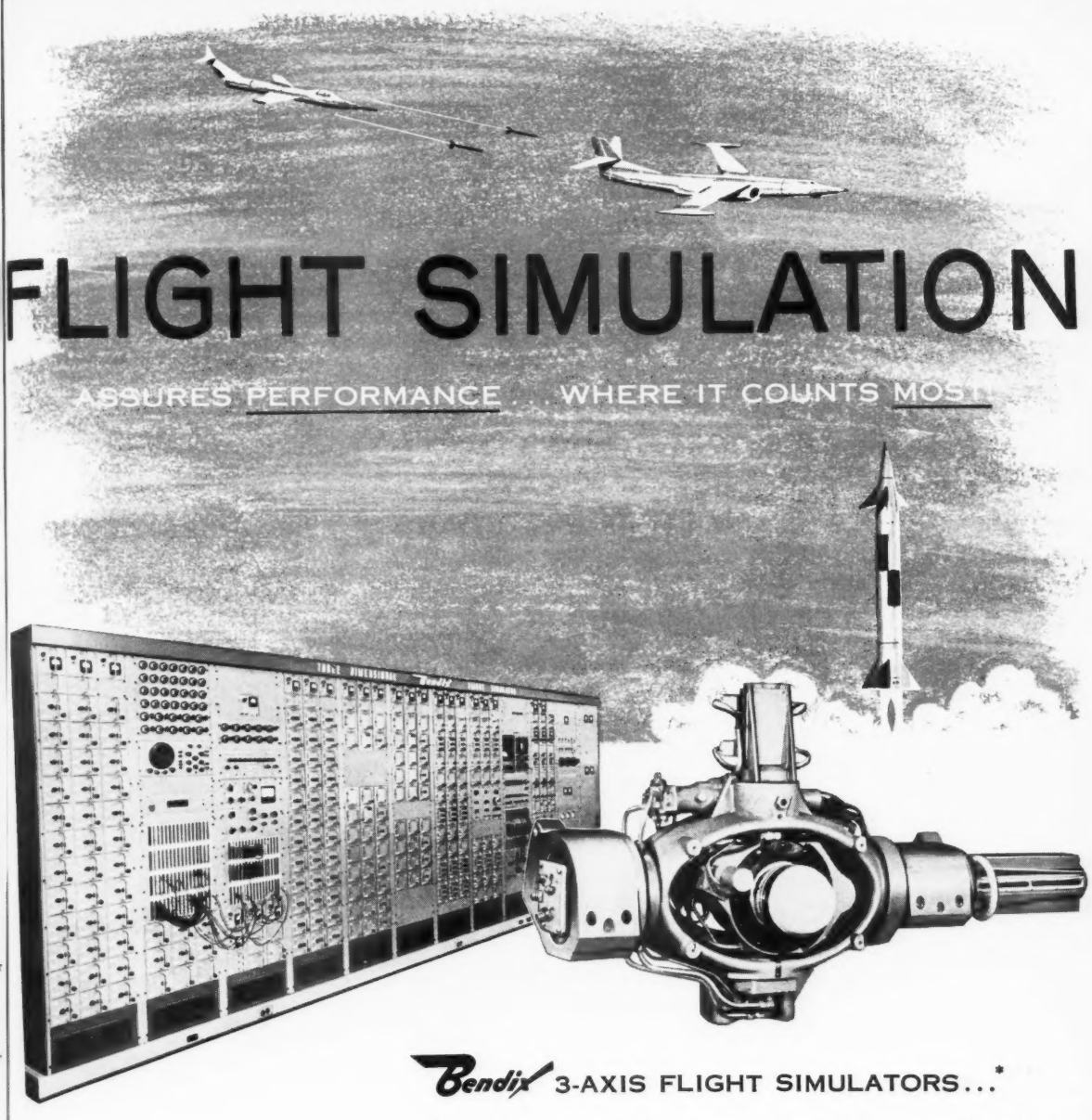

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## Vickers, Inc.

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## Vickers-Armstrongs (Aircraft) Ltd.

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## The Viking Tool & Machine Corporation

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## Vitro Corporation of America

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## Voorhees Walker Smith & Smith

LaBella, Sebastian L., Architectural Designer

## Vulcan Iron Works, Inc.

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## The Waco Aircraft Company

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## H. A. Wagner Company

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## Waku Aero Agency

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## Waldes Kohinoor, Inc.

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## Waldick Engineering Company

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## Wallace & Tiernan Company, Inc.

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## Washington Technological Associates

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## The Weatherhead Company

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## Weber Aircraft Corporation

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## Weems System of Navigation

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## George E. Wells, Incorporated

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## West Coast Airlines, Inc.

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## Western Air Lines, Inc.

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## *Western Aviation*

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## Western Electric Company

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## Western Sky Industries

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### Winzen Research, Inc.

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### *Gary Air Force Base, Tex.*

Goodwin, Lt. George W., III, USAF

### *George Air Force Base, Calif.*

Anderson, Lt. David E., USAF, Electronics Officer, 327th Fighter Interceptor Sq.

### *Goodfellow Air Force Base, Tex.*

Boenig, 1st Lt. Fred H., USAF, Field Maint. Shops Officer, 3547th Field Maint. Sq.
Brown, Lt. Robert A., USAF, Aircraft Maint. Officer

### *Graham Air Base, Fla.*

Bacon, 1st Lt. Merle D., USAF, Student Pilot
Flynn, Lt. Bobby A., USAF

### *Greenville Air Force Base, Miss.*

Fisher, Lt. William Lee, Jr., USAF, Jet Pilot
Pruden, Lt. Albert L., Jr., USAF, Pilot in Training
Scambos, A/C Ernest Taso, 3505 Student Sq.

### *Griffiss Air Force Base, N.Y.*

Hickman, 1st Lt. Billy J., USAF, Proj. Officer, Aero. Engr., Rome Air Dev. Center
Kaczanowicz, John W., Proj. Engr., Mech. Engrg. Design Unit, Rome ADC
Porter, Lt. Samuel R., USAF, Rome Air Devel. Center

### *Laurence G. Hanscom Field, Mass.*

Chrisinger, Capt. John E., USAF, Proj. Engr., Exp. Airborne Engrg. Br. 6520th Support Wing (Test)
Etherington, Lt. Donald J., USAF, Aero. Engr.—Prelim. Des. & Performance Sect., Exper. Airborne Engrg. Br.
Gionfriddo, Maurice P., Aero. Engr., 6520th M&S Gr.—CREOM

### *Harlingen Air Force Base, Tex.*

Kunz, Lt. Richard E., USAF, Student Officer

### *Hill Air Force Base, Utah*

Kale, Lt. Gerald A., Struct. Repair Engr., Hq. OAMA
Kolozsi, Lt. John J., USAF
Whitehead, Capt. John L., Jr., USAF, Test Pilot (Jets)

### *Holloman Air Force Base, N.M.*

Anderson, 1st Lt. Raymond W., USAF, Pilot & Asst. Proj. Officer, F-102 Proj.
Bergman, 1st Lt. John F., USAF, Asst. Ch., Range Operations Office
Braun, Gerhard W., Ch., Analysis Br., Tech. Analysis Div., ADC
Deutsch, Jeffrey Stanton, USAF Proj. Officer, XQ-4 Proj., HADC
Eber, Gerhard R., Tech. Dir., Directorate of Labs., ADC
Fernandez, 1st Lt. C. P., USAF, Aero. Engr.
Kleinman, Capt. Robert B., USAF, Ch., Missile Countermeasurers Lab., HADC
Nelson, Capt. Charles E., USAF, Ch., Instrumentation Sect., 6580th Test Sq. (Spec.)
Norwood, Major Howard L., Jr., USAF, Asst. Ch., Flight Determination Lab.
Prodan, Capt. John, USAF, GAR-1 Proj. Officer, ADC
Steinhoff, Ernst A., Deputy Dir., R&D; Scientific Advisor to Commanding Gen., ADC
von Handel, Paul F., Cons. Electronic Scientist, Tech. Analysis Div., ADC
Warren, Lt. Charles A., USAF, R&D Proj. Officer

### *Hunter Air Force Base, Ga.*

Voss, Capt. William R., USAF

### *Inglewood, Calif., ARDC Western Development Division*

Bouvier, Arthur O., Jr., Proj. Engr.
Eisert, Fred J., Propulsion Br., Ballistic Missiles Office
Ely, Col. Lawrence D., USAF, Asst. for Tech. Gr.
Jasen, Capt. Frank S., USAF, R&D Proj. Administrator
Lehmann, Capt. E. C., USAF, Aero. Engr., Airframe & Armament Gr.
Logan, Capt. Lewis B. C., USAF, Asst. Ch., Comd. Sup. Gp.
Peabody, Maj. Prentice B., USAF
Sheppard, Col. William A., USAF, Deputy Comdr., Program Mgmt.
Stevenson, Major Robin, USAF, R&D Proj. Admin.
Stokes, Major Jone Clifton, USAF, R&D Admin., Office of Deputy Comdr.

### *Kelly Air Force Base, Tex.*

Draper, J. W., Jr., Ch., Information Services, Continental Div., MATS
Robinson, William C., Ch. Proj. Engr., Comptroller
Smith, Col. Claude W., USAF, Cdr., 1700th Air Transport Gr., MATS
Tolosko, 2nd Lt. Raymond J., USAF, Struct. Engr., Hq. SAAMA

### *Kirtland Air Force Base, N.M.*

Anderson, Lt. David A., USAF, Proj. Officer, Devel. Directorate, AFSWC
Bennett, Major Charles J., USAF, Ch. Pract. Bomb Br., Dev. Dir., Hq. AFSWC
Boatwright, Lt. Col. Lewellyn T., Jr., USAF
Carlson, Col. Francis B., USAF
Dalton, Capt. John D., USAF, R&D Staff Asst., Special Weapons Center
Diener, Lt. William E., USAF, Proj. Officer, AFSWC
Evert, Jack K.
Gogan, Harry L., Asst. Ch., Tech. Proj. Sect. (Fighter), 4929th Sq. (Dev.), AFSWC
Harris, Lt. Martin H., USAF, Proj. Engr., Bomber Unit, Aircraft Sect., Devel. Directorate, Air Force Special Weapons Center
Hume, Major William H., USAF, Ch., Tech. Operations, 4929th Test Sq. Devel.
Lederer, 1st Lt. John M., USAF, Proj. Engr.
Morris, Capt. Robert P., USAF, Proj. Engr., AFSWP
Ramsey, Capt. Frank D., USAF, Devel. Directorate, AFSWC
Sater, Lt. Stanford J., USAF, Proj. Engr.
Tohman, Lt. Warren R., Devel. Directorate, Hq., Special Weapons Center
Wente, Capt. Hermann A., Flight Test Maint. Officer, 93rd Fighter Intcp. Sq.
Yarnell, Lt. Warren L., USAF, Proj. Officer, Devel. Directorate, AF Special Weapons Center

### *Lake Charles Air Force Base, La.*

Tiel, Lt. Robert P., USAF, Propulsion Br. Ch.

### *Langley Air Force Base, Va.*

Roché, Jean A., Aero. Devel. Engr.; currently assigned as Air Force Devel. Field Rep., NACA Labs.
Scott, Lt. Col. Robert R., USAF, Sq. Comdr., 510th Fighter Bomber Sq.

### *Laredo Air Force Base, Tex.*

Balser, Lt. Richard A., USAF, Student Pilot
Jenkins, Lt. Charles R., USAF, Basic (Jet) Single Engine Pilot Training
Proffitt, 1st Lt. James Vernon, Jr., USAF, Jet Fighter Pilot Instr.

### *Larson Air Force Base, Wash.*

Champoux, Lt. Ronald James, USAF, Maint. Officer (T-33)
Ernst, Lt. Thomas E., USAF, Hq. Sq., 71st SRW
Laisure, Lt. Corliss U., USAF, 82nd Strat. Recon. Sq.

### *Laughlin Air Force Base, Tex.*

Mitchell, Lt. John F., USAF, Student Pilot, Basic Jet Flight Training

### *Lawson Air Force Base, Ga.*

Bills, 1st Lt. Richard L., Jr., USAF, Pilot, 776th Troop Carrier Sq.

### *Lockbourne Air Force Base, Ohio*

Pierce, Lt. G. Alvin, USAF, Armament Systems Officer, 91st Armament Electronics Maint. Sq., 91st Strategic Recon. Wing
Scambos, Lt. Ernest T., USAF, Aviator
Wronski, William R., B-47 Aircraft Comdr., 4th Strat. Recon. Sq., 26th Strat. Recon. Wg.

### *Los Angeles, Calif.*

Peirce, Chester, Guided Missile Devel. Control Engr., USAF Devel. Field Office
Swan, Major Frederic F., USAF, Asst. to Ch., Missiles

### *Lowry Air Force Base, Colo.*

Bassett, 1st Lt. Kimbrough Stone, USAF, Pilot, Air Training Officer, USAF Academy
Bodner, Lt. Robert E., USAF
Bond, Lt. Richard A., USAF, Armament Systems Officer School
Dane, Col. Paul H., USAF, Prof. of Thermodynamics, USAF Academy
Fuchs, Major William R., USAF, Asst. Prof., Dept. of Math., USAF Academy
Trayna, Major Casimir J., USAF, Asst. Ch., Unit Training Br., Dept. of Special Weapons Training

### *MacDill Air Force Base, Fla.*

Ball, Capt. John T., Jr., USAF, Aero. Engrg. Proj. Officer, B-47 Operational Engrg. Sect., SAC
Green, Major Joseph, USAF, Aero. Engr., B-47 Operational Engrg. Sect.
Meadows, 1st Lt. Alan S., USAF, KC-97, Co-Pilot, 350th Air Refueling Sq.

### *Malden Air Base, Mo.*

Real, 2nd Lt. Mackey J., Jr., USAF, Student Officer

### *Marana Air Base, Ariz.*

Kastner, Lt. Robert E., USAF, Primary Pilot Training
Michel, Lt. F. Curtis, USAF, Primary Pilot Training
Roberts, Lt. James F., USAF, Student Pilot
Tyndall, Lt. Robert R., USAF, Pilot

### *March Air Force Base, Calif.*

Perevuznik, Capt. John, USAF, Navigator KC-97, 320th Air Refueling Sq.

### *Mather Air Force Base, Calif.*

Foster, Joseph J., III, Flight Test Maint. Officer
Real, Lt. Mackay J., Jr., USAF, Sr. Dir., A.D.C., 668th ACWRON
Sowell, Lt. Joseph Thomas, USAF, Student Officer, Pilot Training
Wright, Capt. Harold V., USAF, Instr.—Sr. Observer, Tech. Specialist Course

### *Maxwell Air Force Base, Ala.*

Anderson, Lt. David H., USAF
Farr, Major John W., USAF, Student, Air Command & Staff School
Fowler, Lt. Col. John R., USAF, Student, Air Command & Staff School, Air Univ. Command
Gilluly, Lt. Col. John W., USAF, Student, Air Command & Staff College

Marks, Lt. Col. Mortimer D., USAF, Student, Air Command & Staff School
**Schramm, Major Ned, Jr., USAF, Student, Air Command & Staff School**
Tisdale, Major, James W., Jr., USAF, Student, Air Command & Staff School
Turton, Lt. Col. John S., USAF, Student, Air Command & Staff School
White, Major James H., USAF, Instr., Operations Dept., Air Command & Staff College
Williams, Major Thomas G., USAF, Attending Air Command & Staff College

### *McChord Air Force Base, Wash.*

Moran, Lt. Lawrence Michael, USAF, Maint. Officer, 33 Air Transport Sq.
Papazian, Major Leon F., USAF, Maint. & Materiel & Performance Engr., 1705th Air Tr. Gp.
Thomas, Lt. Richard G., USAF, Pilot, All-Weather Intcp. Sq.

### *McClellan Air Force Base, Calif.*

**Bradley, Capt. Richard W., USAF, WADC Engrg. Rep.**
Cumberpatch, Major James R., USAF, Ch., Maint. Plans & Programs Office, Sacramento Air Materiel Area
**Fishburne, Lt. Col. Paul L., USAF, Ch., Engrg Div., Maint. Directorate, Sacramento Air Material Area**
Grenier, Capt. Louis A., Jr., USAF, Industrial Specialist, AF Production & Procurement
Martinson, Theodore V., Ch., Weapons Support Engrg. Div.
Pursell, Lynn C., Jr., Supvr., Engrg. Br., SMMHA
**Sweeney, Capt. Edwin, USAF, Proj. Officer—Team 101**

### *McConnell Air Force Base, Kan.*

Berkowitz, Lt. Herbert, USAF, Navigation-Radar Instructor

### *Mitchel Air Force Base, N.Y.*

**Birdseye, Lt. David E., USAF**
Bowlby, Ronald L., 1851st AACS

### *Moody Air Force Base, Ga.*

Prestjohn, Lt. Lawrence O., USAF, Training Aids Officer
Rast, 1st Lt. James J., USAF, Radar Observer
Troup, Capt. Duane H., USAF

### *Moore Air Base, Tex.*

Fehrenbacher, Lt. Paul L., USAF

### *Norton Air Force Base, Calif.*

**Dill, Major Alvin W., USAF, Ch., Tech. Data Research Br., Weapons Analysis Div., Deputy Insp. Gen.**
**Muldoon, Major James E., Jr., USAF, Proj Officer, Weapons Analysis Div., Deputy Insp. Gen.**
Norris, Capt. George W., Propulsion Engr., Office of the Insp. Gen., USAF
Pennoni, Richard J., Ch., Struct. Specialist, Directorate of Flight Safety Research, Office of the Insp. Gen., Hq. USAF
Poladian, Capt. Robert, USAF, Aero. Engr., Design Devel., Directorate of Office Insp. Gen.

### *Offutt Air Force Base, Neb.*

Calvert, Clarence E., Aero. Research, Design & Devel. Engr., SAC
McCarthy, John F., Jr., Operations Analyst, Hq., SAC
Meyer, Lt. Col. Alvin F., Jr., USAF, Ch. Ind. Hygiene Engr., Hq., SAC
O'Meara, Francis E., Operations Analyst, SAC

### *O'Hare Internat'l. Airport, Ill.*

Clark, Lt. Harold L., USAF, Aircraft Maint. Officer, 56th Fighter Gr.

### *Olmsted Air Force Base, Pa.*

Mellinger, Harry K., Ch., Logistical Data Processing Devel. Office, Hq., MAAMA

### *Orlando Air Force Base, Fla.*

Horn, Capt. Robert P., USAF, Ch., Procurement Div., Hq., Air Photographic & Charting Serv.
Walker, Col. Richard L., USAF, Insp. Gen., Air Rescue Service

### *Otis Air Force Base, Mass.*

Evans, 1st Lt. Robert James, USAF
Williford, Lt. H. S., Jr., USAF, Pilot

### *Patrick Air Force Base, Fla.*

Albrecht, Lt. Stanley F., USAF, Aero. Engr., Test Engrg. Div., Directorate of Tests, AFMTC
Ellison, 1st Lt. Donald Warren, USAF, Aero. Engr., Missile Test Center
McDonald, Capt. Albert J., USAF, Ch., IM-99 Evaluation Br., Directorate of Test Engrg.
Petters, James R., Mech. Engr.
Reynolds, Capt. Robert H., USAF, R&D Admin., AFMTC
Roop, Capt. John M., USAF, Dep. Ch., Install. Div., Dep. for Materiel
Wayne, Capt. James C.
Yasecko, Joseph S., Supervisory Electronic Engr.
Yates, Maj. Gen. Donald N., USAF, Commander, Air Force Missile Test Center

### *Perrin Air Force Base, Tex.*

Boger, 1st Lt. Churchill S., Jr., USAF, Aircraft Maint. Officer, 3555th Flight Line Maint. Sq.
Windler, Lt. Milton L., USAF, Pilot, Class 56-L, 355 Combat Crew Tng. Sq.

### *Pinecastle Air Force Base, Fla.*

Taylor, Capt. Samuel G., Jr., USAF, B-47 Airplane Comdr.

### *Pope Air Force Base, N.C.*

Bradley, Lt. Richard G., USAF, 464 Troop Carrier Wing
Clark, Lt. Robert H., USAF, Supply Officer
Johnston, Lt. Sidney F., Jr., USAF, Air Base Gr. Adjutant & Pilot

### *Portsmouth Air Force Base, N.H.*

Goldberg, Lt. Louis M., USAF, Maint. Br.

### *Randolph Air Force Base, Tex.*

Campbell, Paul A., Dir. of Research, School of Aviation Medicine

### *Reese Air Force Base, Tex.*

Grassan, Lt. George D., USAF, Pilot
Menard, Lt. Joseph A., Student Pilot

### *Robins Air Force Base, Ga.*

Romanick, Lt. Joseph J., Jr., USAF, Aircraft Struct. Repair Engr., Hq. Air Material Area
Ross, Lt. Col. James S., USAF, Ch. Production Div., Hq., WRAMA

### *Scott Air Force Base, Ill.*

**Burg, Lt. John R., USAF, 798 A.C. & W. Sq.**
Collelo, Pasco D., Communications Officer, USAF
Johnson, Capt. Jesse H., USAF, Operations Officer, 3310th Field Maint. Sq.

### *Sewart Air Force Base, Tenn.*

DiCamillo, Lt. Joseph R., USAF, Production Control Officer, Field Maint. Sq.
Gregoire, Lt. Mark C., Operations Officer, 314th Troop Carrier Gr. (C-119)
Johnson, Capt. Jesse H., USAF, Operations Officer, 313th Troop Carrier Gr.

### *Shaw Air Force Base, S.C.*

Laughlin, Lt. Omer C., USAF, Asst. Gr. Maint. Officer, 432nd Tac. Recon. Gr.

### *Smoky Hill Air Force Base, Kan.*

Krell, Lt. Jordon A., USAF, Navigator, 310 ARS
Wetzel, Lt. Col. Albert J., USAF, 40th Bomb Wg. (SAC)

### *Spence Air Base, Ga.*

Meiners, Lt. Herman P., Jr., USAF, Student Pilot, 3302 Pilot Training Gr.

### *Stallings Air Base, N.C.*

Stump, Lt. John P., Jr., USAF

### *Stewart Air Force Base, N.Y.*

Davis, Lt. Richard L., USAF, Aircraft Maint. Officer

### *Suffolk County Air Force Base, N.Y.*

Muckey, Donn Roger, USAF, 519th Material Sq.

### *Thule Air Base, Greenland*

Crandall, Major Edmund B., USAF, Production Control Officer, 6607th Maint. & Supply Gr.

### *Tinker Air Force Base, Okla.*

Donohue, 1st Lt. William J., Jr., USAF, Pilot, 458th Strategic Fighter Sq.
Smith, Lawrence Fred, Aero. Engr.—Struct., USAF, OCAMA

### *Turner Air Force Base, Ga.*

Putnam, Lt. Leslie R., USAF, 811th Supply Sqd.

### *Vance Air Force Base, Okla.*

Hansen, 1st Lt. Robert H., USAF, Student Pilot
**Schumann, Capt. Richard P., USAF, Flight Test Maint. Officer, Hq. Sq. 3575th M&S Gp.**

### *Walker Air Force Base, N.M.*

Ekern, Capt. Harold O., USAF, Pilot, 830 Bm. Sq., 509th Bm. Wg.
Harmatys, Capt. Casimir R., USAF, OIC Fabrication Br., 509th Field Maint. Sq.
O'Keefe, Lt. Joseph Kirk, USAF, Maint. Officer, 509th PMS

### *Washington, D.C.*

Bathurst, Maj. Raymond J., USAF, Program Control Officer, Asst.—Devel. Programming, DCS/D
Benford, Col. Robert J., USAF (MC), Editor, *Journal of Aviation Medicine*
Bennett, Lt. Col. John W., USAF, Directorate of R&D, Hq. USAF
Berry, Col. James D., USAF, Deputy Ch., Family Housing Div., Hqs., USAF
Boyd, Col. William E., USAF, Deputy Comdr., 11th Air Div. (Defense)
Brown, Lt. Col. George F., USAFR, AF Staff Officer—Aero., Office of Asst. Secy. of Defense (R&D)
Culberston, Col. Allman T., USAF, Ch. Supporting Services Gr., Directorate of R&D
Davidson, Maj. Gen. Howard, USAF (Ret.), Dir., Air Force Aid Society
Denning, Vaughn E., R&D Staff Officer
Douglas, James H., Under-Secy. of the Air Force
Hasert, Chester N., Tech., Dir., Scientific Advisory Bd.
Keller, Major Howard W., USAF, AF Devel. Field Rep., USN BuOrd.
Krieger, Col. A. E., USAF, Ch., Tactical Missile Div., Asst. Ch. of Staff—Guided Missiles
Lawyer, Major John E., USAF, Dir. of Research & Devel., Hq. USAF
Lombard, Albert E., Jr., Scientific Advisor, Directorate of R&D, Hq.
Mihaloew, Lt. John A., USAF
Nielsen, Lt. Col. William C., USAF, Asst. for Guided Missiles, Strategic Air Gr., Directorate of R&D, Deputy Ch. of Staff/Devel.
Pearsall, Major David W., USAF, Devel. Div., Armed Forces Special Weapons Proj.
Putt, Lt. Gen. Donald L., USAF, Dep. Ch. of Staff—Devel.
Quarles, Donald A., Secy. of the Air Force
Robinson, Lt. Col. James B., III, USAF, Field Rep., AF Devel. Field Office
Ryan, Lt. Col. Lloyd F., Office, Asst. for Devel. Planning, DCS/D
Saavedra, Capt. Joaquin A., USAF, Aero. Engr.
Schlatter, Brig. Gen. George F., USAF
Shuler, William T., Operations Analyst
Sweet, Lt. Col. Floyd J., USAF, Secy., Scientific Advisory Board, Office, Ch. of Staff
Twining, Gen. Nathan F., USAF, Ch. of Staff
Voyles, Lt. Col. James H., Jr., USAF, Pilot, R&D Administrator, Hq. Command
Wellman, Major Roy J., Aero. Div., DCS-D, Directorate Research & Devel.
Wilkes, Ben Furman, Aero. Powerplant (F&L) Engr. AFDRD-AN
Wise, Lt. Col. Jowell C., USAF, Procurement & Production DCS/M, Hq. USAF
Wodrich, Lt. Col. Edmund Gillette, USAF, AF Advisor to Staff Dir. for Standardization, OASD (S&L)

### *Webb Air Force Base, Tex.*

Ball, Lt. Robert, Jet Fighter Pilot Instructor
Corlett, Lt. Howard G., USAF, Air Electronics Officer
Gregoire, Lt. Mark C., USAF, Jet Fighter Pilot
Morgan, Lt. William H., USAF, Pilot

### *Westover Air Force Base, Mass.*

Cameron, Capt. Robert J., USAF, Communications Engrg. Officer
Heilenday, F. W., Operations Analyst, Hq., 8th AF

### *Wright-Patterson Air Force Base, Ohio*

Appold, Col. Norman C., USAF, Ch., Power Plant Lab., WADC, ARDC
Arcier, A. Francis, Scientific Advisor, Air Tech. Intelligence Center, Directorate of Intelligence
Bailey, Cecil D., Instructor, Dept. of Mechanics, USAFIT
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Barbagallo, John L., Asst. Proj. Engr., USAF Aircraft Flight Handbooks
Barden, William A., Ch., Operations Div., ASTIA
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Benjamin, 1st Lt. Robert B., USAF, R&D Staff Asst., Directorate of Systems Management, Hq. ARDC
Bielkowicz, Peter, Assoc. Prof. of Aero. Engrg., USAFIT

Bittner, Raymond A., Ch., Small Power Plant Sect., & Contracting Officer, AMC
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Bonomo, 1st Lt. Philip J., USAF, Flight Test Engr., WADC
Boyd, Major Gen. Albert, USAF, Comdr., WADC
Boykin, J. Arthur, Jr., Asst. Ch., Bomber Aircraft Br., WADC, ARDC
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Browning, 1st Lt. Bob D., USAF, Liaison Engr., Instrument Br., Flight Control Lab., WADC
Brulle, Capt. Robert V., USAF, Instr.—Aero. Engrg., USAFIT
Bruner, Lt. Col. Frederick W., USAF, Ch., C-130 Weapon System Proj. Office, ARDC
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Bunch, Col. Clare W., USAF
Burggraf, Lt. Odus R., USAF
Burkett, Lt. James Edward, USAF, Proj. Officer, Special Test Unit, WADC
Calhoun, Maj. John D., USAF, Aero. Engr., ARDC Det. #1
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Cannon, Lt. Clifford D., USAF, Proj. Engr., Power Plant Lab., WADC
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Casaburi, Major Robert R., USAF, Procurement Inspector, Inspector Gen. Office
Chamberlain, Major Clarence N., Jr., USAF, Proj. Engr., Weapon System Management, ARDC
Champlain, Lt. Col. Daniel D., USAF, Ch., C-123, Weapon Systems Proj. Office, Cargo Div., Directorate Systems Management, ARDC
Charette, Lt. Franklin M., Aero. Engr.
Chilton, Lt. Col. Robert C., USAF, Ch., F-84/F-105 Sect., Hq. AMC
Chuprun, Lt. John, Jr., USAF, Proj. Engr., Bomber Devel., WADC
Clarke, Capt. Howard D., USAF, C-97 Weapon Systems Proj. Officer, WADC
Clay, James T., Proj. Engr., Bomber Devel. Sect., Design Br., Aircraft Lab., WADC
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Clementon, Lt. Col. Gerhardt C., USAF, Prof. in E.E., USAFIT
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Davis, Lt. Horace Max, USAF, Proj. Engr., Flight Control Lab. WADC
Davison, Lt. Paul H., USAF, Aircraft Performance Engr., WADC
Decker, Capt. Ralph S., Jr. USAF, Proj. Engr., Liquid Rocket Engines, Power Plant Lab., WADC
DeMent, William H., Aerodynamic Devel. Engr.
Deptula, Capt. Alfred R., USAF, Proj. Engr., Aircraft Lab., WADC
deRussy, Col. John H., USAF, Ch., Operational Training & Logistic Concepts Div., Dir. of Nuclear Systems
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Downing, Reginald H., Dean, Resident College, USAFIT
Drown, Capt. Clifford F., USAF, Air Tech. Intell. Center
Du Bois, R. Gerard, Aero. Engr., WADC
Dunham, Seymour W., Ch., Missile Design Sect., WCLSD-3, WADC
Dunn, Walter P., Proj. Engr., Analysis Sect., Dynamics Br., Aircraft Lab., WADC
Dunning, Major Leslie L., USAF, USAFIT
Drown, Capt. Clifford F., Ch. Indus. Engrg. Br., USAF Air Tech. Intelligence Center
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Edstrom, Clarence R., Inst., Aero. Dept., USAFIT
Engelson, Joseph, Description Technician, A.F. Cataloging & Coordinating Office Supply Div., AMC
Farr, Major John W., Aero. Engr., ATIC
Fay, Joseph Patrick, Asst. Ch., IM-70 Weapon System Proj. Office, Hq. ARDC
Fehrman, Capt. Alvin L., USAF, Instructor, USAFIT
Feicht, Maj. Edward R., WADC
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Fiore, Anthony W., Aerodynamic Research Scientist, Aero. Research Lab., WADC
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Flinn, 2nd Lt. Evard H., Proj. Engr., WADC
Flood, Capt. Donald L., USAF, Student, US AFIT
Forbragd, Maurice H., R&D Admin., B-66 WSPO, ARDC
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French, Lt. William A., USAF
Friedenthal, Lt. Morton Jack, USAF, Aero. Engr., WADC
Frozina, Casimir J., Aircraft Prelim. Design Engr., WADC
Gareri, Dan J., Aero. Engr., Air Tech. Intell. Center
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Gilluly, Maj. John W., Ch., GFAE Distribution Sect., Procurement Div., HQ., AMC
Goodlett, E. Ross, Asst. for Procurement Cargo & Special Aircraft Br., AMC
Goodrich, Capt. John W., USAF, Plans Office, Directorate of Research, WADC
Goss, Maj. Quentin J., USAF, Guided Missile Proj. Officer, WADC
Grady, Walter T., Ch., Analysis Sect., Aerodynamics Br., Propeller Lab., WADC
Graetzer, Gunther R., Prof. & Head, Dept. of Aero. Engrg., USAFIT
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Graig, Waldemar A., Ch., New Devel., Rotary Wing Div., Directorate of Weapon Systems Mgt., ARDC
Gravitz, Lt. Sidney I., USAF, Proj. Engr., Dynamics Br., Aircraft Lab., WADC
Green, Major William M., USAF, ARDC
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## Bureau of Ships

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## Naval Installations

*Naval Auxiliary Air Station, Chase Field, Beeville, Tex.*

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*Naval Auxiliary Air Station, Kingsville, Tex.*

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*Naval Auxiliary Air Station, Whiting Field, Milton, Fla.*

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*Naval Auxiliary Air Station, Corry Field, Pensacola, Fla.*

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